SAND87—0027 • UC—80
Unlimited Release
Printed May 1987

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HECTR Version 1.5N – A Modification of HECTR Version 1.5 for Application to N Reactor

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for the United States Department of Energy
under Contract DE-AC04-76DP00789

ACKNOWLEDGMENT

The authors would like to acknowledge the assistance of Arthur C. Payne, Jr., who supplied much of the information describing the operation of key systems and components and assisted in the debugging and checkout of the new models. We would also like to thank Emily Preston, who assisted in preparing the report.

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EXECUTIVE SUMMARY

United Nuclear Corporation (UNC) is engaged in a number of interrelated programs to assure the safe operation of the N Reactor for the remainder of its planned life. These programs include investigating the potential plant response and risk to the public from a number of postulated severe accident sequences. Some of these accident sequences include the potential for fuel degradation and combustible gas production. In order to evaluate the potential threat from hydrogen, UNC has initiated an effort to examine in detail the potential effects of hydrogen released into the confinement. UNC has asked Sandia National Laboratories (SNL) to assist in this work by performing analyses of hydrogen behavior within the N Reactor confinement.

Following the accident at Three Mile Island, the Nuclear Regulatory Commission sponsored a program at SNL to investigate hydrogen behavior in light water reactor containments. A major part of this program was the development of HECTR (Hydrogen Event Containment Transient Response), which is a computer code to model the transport and combustion of combustible gases during postulated accidents in Light Water Reactors (LWRs). In order to perform the necessary calculations for N Reactor in a realistic manner, some modifications to the most recent version of HECTR (Version 1.5) were required. This report describes the changes to HECTR Version 1.5 that were necessary to produce HECTR Version 1.5N, which is the version applied to N Reactor. This document is a supplement to, rather than a replacement for, the HECTR Version 1.5 User's Manual.

HECTR is a lumped-parameter containment analysis code developed for calculating the containment atmosphere pressure-temperature response to combustion. Six gases--steam, nitrogen, oxygen, hydrogen, carbon monoxide, and carbon dioxide--are modeled in HECTR along with sumps containing liquid water. To calculate the pressure, temperature, and composition of gases in a containment, the containment is divided into "compartments" with flow between compartments occurring through "junctions." Flows between compartments are pressure and buoyancy driven with inertial and resistance terms included. Steam is treated as a real gas, and the other gases are treated as ideal. Gases in each compartment are instantaneously mixed, and source terms are user-specified. Simplified conservation equations are solved to determine compartment and junction conditions during the transient. The thermal response of surfaces and equipment in the containment can also be calculated in HECTR, using either one-dimensional finite difference slabs or lumped masses. Models are included to calculate combustion, radiative and convective heat transfer, steam condensation or evaporation, and containment leakage. The engineered safety features (ESFs) modeled in HECTR are containment sprays, fans, fan coolers, ice condensers, sumps, suppression pools, and heat exchangers.

The basic physical models in HECTR remain unchanged for version 1.5N. Most of the changes are in the logic models dealing with system actuation and junction opening and closing.

The containment spray model has been altered to allow multiple spray trains with separate actuation criteria for each train. Each train can now be actuated based on combinations of pressure or temperature signals from different locations. The spray trains can be individually turned off and restarted at later times.

Two additional types of containment leaks were added to treat the steam vents and vacuum breakers at the N Reactor. The steam vent option allows the vents to open based on exceeding a specified pressure and to later close based on a timer. The closure can be specified to occur over an additional time interval. Different criteria can be used for individual steam vents, if desired. The vacuum breaker option allows a containment leak to open as a function of differential pressure between the compartment and the outside atmosphere. Tabular input is used to define the flow area versus differential pressure relationship.

An additional junction option was added for the cross vents between the 105 and 109 buildings at N Reactor and for the filter building isolation valves. This option allow a junction area to be controlled by trips and tables. Different trips and tables can be specified for opening or closing the junction. For example, a junction could be specified to open according to a flow area versus differential pressure table until a compartment pressure exceeds a setpoint, then reclose following a flow area versus time table. Finally, this option allows a door to "blow out" if a third trip (e.g., the differential pressure in a particular direction exceeding a specified value) is satisfied. After blowing out, the junction remains fully open for the remainder of the calculation.

This report describes the details of the code changes and also supplies a complete new set of input instructions. Changes associated with the output processor, ACHILES, are also described. A sample problem for the N Reactor confinement is included that utilizes most of the new features of HECTR. For details regarding the fundamental physical models in HECTR and the code structure, the reader should refer to the HECTR Version 1.5 User's Manual.

1. INTRODUCTION

1.1 Background and Objectives

United Nuclear Corporation (UNC) is engaged in a number of interrelated programs to assure the safe operation of the N Reactor for the remainder of its planned life. These programs include investigating the potential plant response and risk to the public from a number of postulated severe accident sequences. Some of these accident sequences include the potential for fuel degradation and combustible gas production. In order to evaluate the potential threat from hydrogen, UNC has initiated an effort to examine in detail the potential effects of hydrogen released into the confinement. UNC has asked Sandia National Laboratories (SNL) to assist in this work by performing analyses of hydrogen behavior within the N Reactor confinement.

Following the accident at Three Mile Island, the Nuclear Regulatory Commission sponsored a program at SNL to investigate hydrogen behavior in light water reactor containments. A major part of this program was the development of HECTR (Hydrogen Event Containment Transient Response), which is a computer code to model the transport and combustion of combustible gases during postulated accidents in Light Water Reactors (LWRs). Following the development and application of several preliminary versions of HECTR, Version 1.0 was released in February 1985 [1]. This version contained several limitations that were corrected with the release of Version 1.5 in April 1986 [2]. In order to perform the necessary calculations for N Reactor in a realistic manner, some modifications to HECTR Version 1.5 were required. This report describes the changes to HECTR Version 1.5 that were necessary to produce HECTR Version 1.5N, which is the version applied to N Reactor. This document is a supplement to rather than a replacement for Reference 2. The initial application of HECTR Version 1.5N is described in Reference 3.

It is anticipated that all of the features of HECTR Version 1.5N will be incorporated into HECTR Version 2.0, which should be released within the next year. Version 2.0 will correct certain shortcomings in Version 1.5 and will add an improved diffusion flame model, updated combustion correlations, and a restart capability.

1.2 Capabilities of HECTR Versions 1.0 and 1.5

HECTR is a lumped-parameter containment analysis code developed for calculating the containment atmosphere pressure-temperature response to combustion. HECTR is also useful for modeling gas transport and combustion experiments and for analyzing experiments involving only the release of steam and liquid water. The reader should refer to References 3 through 8 for more examples of the previous uses and capabilities of HECTR. The capabilities of HECTR Version 1.5 are summarized in Table 1.1.

Table 1.1 Capabilities of HECTR Version 1.5

Feature	Version 1.5
1. Natural Convection/Gas Transport	yes
2. Gases Treated	H_2O, H_2, O_2, N_2, CO, CO_2
3. Implicit Numerics	yes
4. Intercompartment Fans	yes
5. Combustion	H_2 + CO
6. Radiative Heat Transfer	from H_2O + CO_2
7. Convective Heat Transfer	yes
8. Surface Conduction	yes
9. Containment Sprays	yes
10. Ice Condenser	2-D
11. Sumps	yes
12. Mark III Suppression Pool	yes
13. Heat Exchanger	yes
14. Flexible input of source gases	yes
15. Flexible input of energy sources	yes
16. Fan Cooler Model	yes
17. Continuous Burning	yes
18. Containment Leakage/Failure	yes

Six gases--steam, nitrogen, oxygen, hydrogen, carbon monoxide, and carbon dioxide--are modeled in HECTR along with sumps containing liquid water. To calculate the pressure, temperature, and composition of gases in a containment, the containment is divided into "compartments" with flow between compartments occurring through "junctions." As shown in Figure 1.1, each compartment is essentially a gas control volume. Flows between compartments are pressure and buoyancy driven with inertial and resistance terms included. Steam is treated as a real gas, and the other gases are treated as ideal. Gases in each compartment are instantaneously mixed, and source terms are user-specified. Simplified conservation equations are solved to determine compartment and junction conditions during the transient. The thermal response of surfaces and equipment in the containment can also be calculated in HECTR, using either one-dimensional finite difference slabs or lumped masses. Recently, an error was discovered in the treatment of multilayered slabs. This capability has been disabled in Version 1.5N so that only single-layered slabs are treated. Models are included to calculate combustion, radiative and convective heat transfer, steam condensation or evaporation, and containment leakage. The engineered safety features (ESFs) modeled in HECTR are containment sprays, fans, fan coolers, ice condensers, sumps, suppression pools, and heat exchangers.

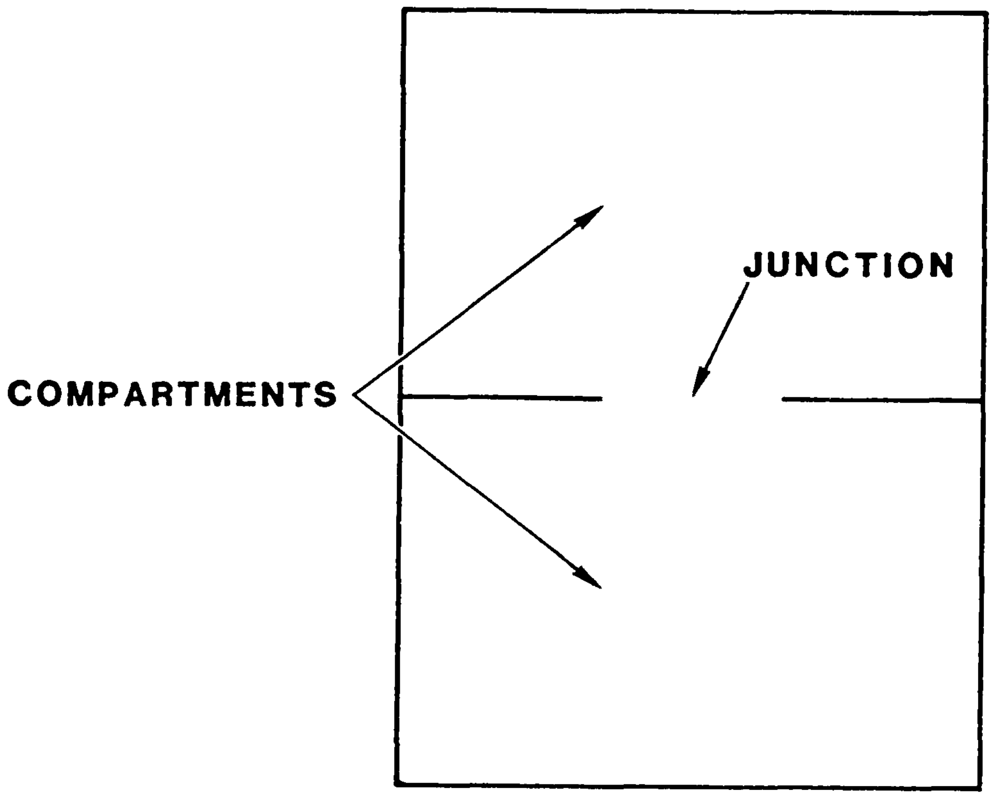


Figure 1.1. HECTR Compartment and Junction Arrangement

HECTR has been developed with emphasis on combustion. It is not intended to model all possible phenomena that might occur during a severe accident. For example, steam explosions, core-concrete interactions, and aerosol transport are not modeled by HECTR. For some accidents, these phenomena may not be important. In other cases, HECTR results can still provide insights when combined with analyses that address the phenomena not modeled in HECTR.

Further, because HECTR is a lumped-parameter code, certain momentum flux and turbulence effects are neglected. The effects of spray entrainment and momentum are also neglected. These code limitations are being examined through comparisons with other codes, including COBRA-NC [9] which contains a finite-difference formulation. Those comparisons will be presented in a future report by UNC. Finally, lumped-parameter codes cannot readily treat the dynamic effects (high-speed flows and shock waves) of flame acceleration or local detonations that can occur for moderate to rich hydrogen mixtures.

1.3 Changes for HECTR Version 1.5N

The basic physical models in HECTR remain unchanged for version 1.5N. Most of the changes are in the logic models dealing with system actuation and junction opening and closing.

The containment spray model has been altered to allow multiple spray trains with separate actuation criteria for each train. Each train can now be actuated based on combinations of pressure or temperature signals from different locations. The spray trains can be individually turned off and restarted at later times.

Two additional types of containment leaks were added to treat the steam vents and vacuum breakers at the N Reactor. The steam vent option allows the vents to open based on exceeding a specified pressure and to later close based on a timer. The closure can be specified to occur over an additional time interval. Different criteria can be used for individual steam vents, if desired. The vacuum breaker option allows a containment leak to open as a function of differential pressure between the compartment and the outside atmosphere. Tabular input is used to define the flow area versus differential pressure relationship.

An additional junction option was added for the cross vents between the 105 and 109 buildings at N Reactor and for the filter building isolation valves. This option allow a junction area to be controlled by trips and tables. Different trips and tables can be specified for opening or closing the junction. For example, a junction could be specified to open according to a flow area versus differential pressure table until a compartment pressure exceeds a setpoint, then reclose following a flow area versus time table. Finally, this option allows a door to "blow out" if a third trip (e.g., the differential pressure in a particular direction exceeding a specified value) is satisfied. After blowing out, the junction remains fully open for the remainder of the calculation.

Some additional minor changes were made to HECTR and also to the output processor, ACHILES. These changes, such as increasing array sizes and modifying output messages, will be described in Chapters 2 - 4.

1.4 Description of This Report

The remainder of this manual provides a description of the changes for HECTR Version 1.5N, along with a complete set of input instructions for using the revised code. The material is presented in a format similar to Reference 2, so users familiar with HECTR Versions 1.0 or 1.5 should have no difficulty using this report. This report is a supplement to Reference 2 and users will have to refer to that document for background information on HECTR.

We caution the user that codes such as HECTR contain many models with significant uncertainties, and the results that are produced must be carefully interpreted. Merely running the sample problems does not qualify one to perform analyses with HECTR. It is essential that the user acquire a general understanding both of the methods used and of the physics important to the events being analyzed.

Chapter 2 provides detailed descriptions of the changes to HECTR, including important assumptions and limitations. Chapter 3 provides a complete set of input instructions. Chapter 4 provides information concerning changes in the HECTR output, and Chapter 5 contains an example problem for the N Reactor.

Serious users of HECTR should carefully read Chapter 2 of this report and the first two appendices of Reference 2. Appendix A of Reference 2 contains details of the models in HECTR and Appendix B provides a detailed breakdown of the code structure.

To get started, we recommend reading Chapters 2 and 3 of Reference 2 to obtain a general understanding of the physical models and numerical methods used in HECTR. This should be followed by setting up and running the sample problem in Chapter 5, referring to Chapters 3 and 4 as necessary. Frequent referral to Chapter 2 of this report and Chapter 3 of Reference 2 is useful when setting up a new problem. Those desiring to make changes to HECTR will find Appendix B of Reference 2 useful, although changes should be attempted only when a thorough understanding of and familiarity with the code are achieved.

Throughout the remainder of the report "HECTR" will refer to Version 1.5N unless otherwise specified.

2. CHANGES TO HECTR VERSION 1.5 FOR N REACTOR

This chapter describes in detail the changes that were made to HECTR Version 1.5 to create Version 1.5N. For each new model, relevant equations are presented along with significant assumptions and limitations.

2.1 Revised Spray Model

This section describes the details of the HECTR spray model. The changes to the HECTR spray model involve the addition of models to handle sprays in pure steam atmospheres and new logic to allow multiple independent spray trains. This section describes the spray model in its entirety and is a replacement to Section A.2.7 of Reference 2.

Containment sprays are important in preventing long-term steam overpressurization and in limiting the pressure and temperature effects of combustion. The containment spray model in HECTR is flexible, allowing injection of sprays into any compartment, carryover of sprays into compartments and sumps below, and either injection of water from an outside source or recirculation from a specified sump. HECTR is not limited to a single drop size; a distribution of drop sizes can be specified.

2.1.1 Spray Actuation Logic

HECTR has been modified to treat multiple independent spray trains. Currently, the array sizes are set to treat as many as four independent trains. Each train can be independently actuated in either a manual or automatic mode. In the manual mode, the sprays are simply set to be turned on or off at specific times. They may be turned on or off multiple times during a calculation and may also be turned off following automatic actuation.

In the automatic mode, a spray train is actuated based on combinations of compartment atmosphere pressure and temperature setpoints. The general logic arrangement is shown in Figure 2.1. Up to five top-level criteria can be specified, any one of which can result in spray actuation ("OR" logic). For each top-level criteria, up to ten second-level criteria can be specified, all of which must be met for the top-level criteria to be true ("AND" logic). A second-level criteria is true if a combination of pressure and temperature setpoints are met for specified compartments. For the n compartments specified for a particular second-level criterion, both the temperature and the pressure must exceed chosen setpoints. If the user desires to actuate the sprays based solely on pressure, then a very low temperature setpoint can be specified. The second-level criteria are examined based on m out of n compartments being true, where m is user specified and n is the number of compartments specified for examination (up to ten compartments per second-level criteria).

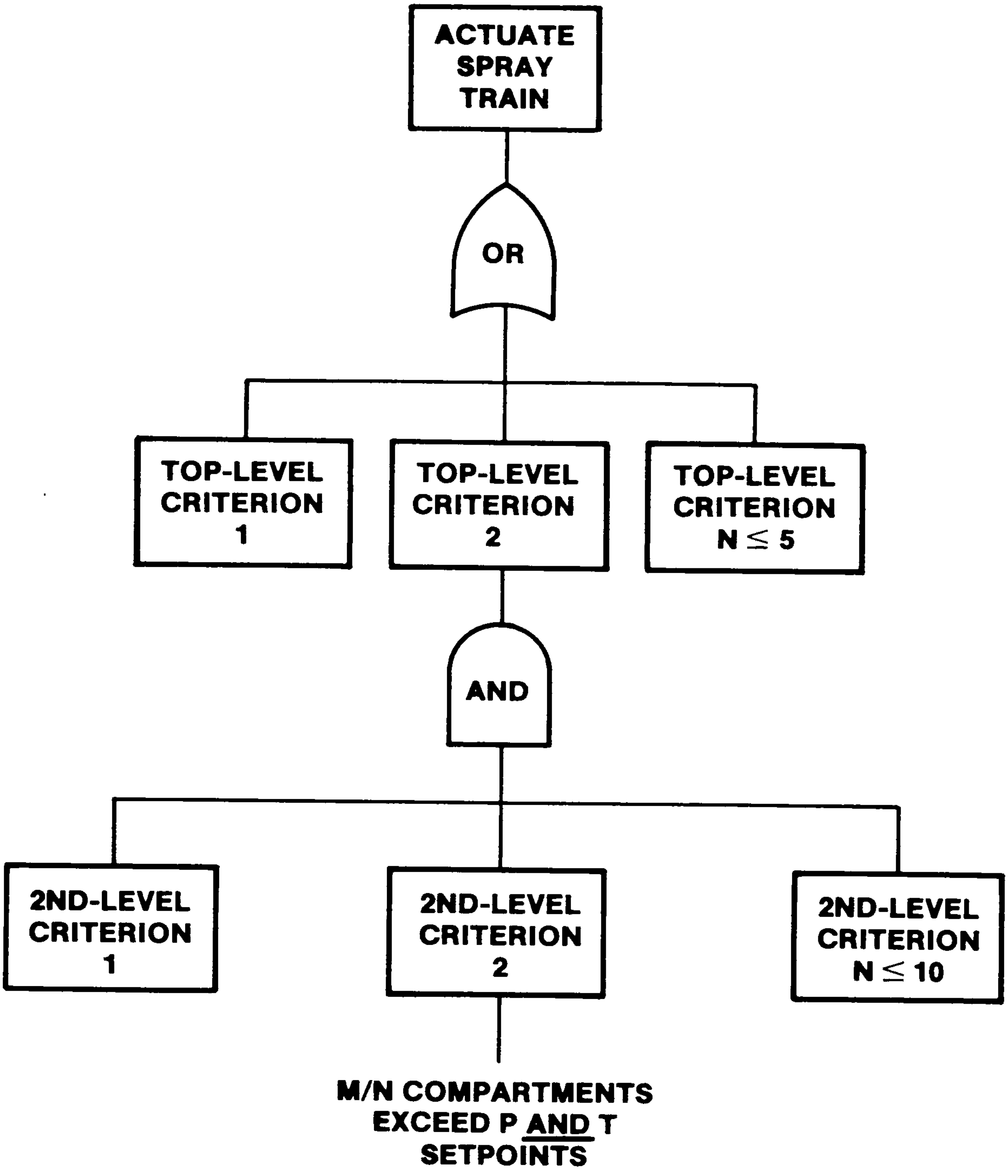


Figure 2.1. General Spray Actuation Logic

This approach allows the user to specify such criteria as spray actuation on one out of six pressure sensors in the N Reactor steam generator cells plus a pressure signal in the pipe gallery. This should become more clear upon examination of the sample problem in Chapter 5.

The containment spray systems in most commercial LWRs can operate in an injection mode or in a recirculation mode. In injection mode spray water is injected from a constant temperature external source. In recirculation mode, water is taken from a sump within containment, passed through a heat exchanger, and then injected back into containment. HECTR includes models for both injection and recirculation, with switchover from injection to recirculation occurring at a specified time following spray actuation. The spray system at N Reactor operates exclusively in the injection mode; thus, the recirculation capability is not important in that case. Because of this, the recirculation logic was not expanded to treat multiple trains for Version 1.5N. The user can still specify recirculation with multiple spray trains, but the actuation logic may not be as desired. If recirculation is specified for multiple trains that actuate at different times, all of the trains will be switched to recirculation at the same time. Further, the switchover will be based on the last train actuated, i.e., the switchover time is reset each time a new train is actuated. For these reasons, the user should be very careful in attempting to utilize the recirculation option with a multiple train configuration.

2.1.2 Spray Model for Atmospheres Containing Noncondensables

The drops from containment sprays are assumed to be isothermal, spherical, and traveling at the terminal velocity corresponding to their instantaneous size and mass. They are tracked through a compartment to the bottom where their final temperature and mass determine the heat- and mass-transfer rates to the compartment atmosphere. A user-specified fraction of the drops that have reached the bottom of a compartment is allowed to fall into lower compartments. Drops not falling into other compartments can be transferred to a specified sump.

The gas in a compartment is assumed to be homogeneous with none of its properties changing during the fall time of the drops. Therefore, the solutions represent a quasi-steady-state model. The differential equations describing drop behavior (mass, temperature, and distance fallen) are valid for both condensation on and evaporation from the drops and are presented below.[10,11]

$$\frac{dm}{dt} = -2\pi p_g D(1 + .25Re^{1/2}Sc^{1/3})D_c \ln(1 + B) \qquad (2.1)$$

$$\frac{dT_d}{dt} = \frac{1}{mC_{PL}}\left[\frac{C_p(T_d - T_b)}{(1 + B)^{1/Le} - 1} + h_{fg}\right]\frac{dm}{dt} \qquad (2.2)$$

$$\frac{dz}{dt} = \left[\frac{4}{3}\,\frac{(p_d - p_g)gD}{p_g C_D}\right]^{1/2} \qquad (2.3)$$

Here,

m = droplet mass (kg)

T_d, T_b = droplet and bulk gas temperatures (K)

z = droplet fall height (m)

t = time (s)

p_g, p_d = gas and droplet densities (kg/m^3)

D = droplet diameter (m)

Re = Reynolds number

Sc = Schmidt number

Le = Lewis number

D_c = diffusion coefficient (m^2/s)

B = mass-transfer driving force = $(Y_d - Y_b)/(1 - Y_d)$

Y_d = mass fraction of vapor at drop surface

Y_b = mass fraction of vapor in bulk gas

C_{PL}, C_p = droplet and gas specific heats (J/kg-K)

h_{fg} = heat of vaporization of water (J/kg)

g = acceleration due to gravity (m/s^2)

C_D = drag coefficient

Both the drag coefficient and diffusion coefficient are calculated internally in HECTR.

The three equations above are reduced to the two equations dm/dz and dT_d/dz by dividing Eqs. 2.1 and 2.2 by Eq. 2.3. The equations are then solved using a standard Runge-Kutta differential equation solver. The spray model has been formulated to maximize computational efficiency. If a drop reaches an equilibrium temperature (determined by setting Eq. 2.2 to zero and solving for T_d), then HECTR switches to integrating only the dm/dz equation. When solving the equations, numerical problems may arise if the droplet completely evaporates during its fall. The velocity (and thus the Reynolds number) of the droplet will decrease as its mass decreases. Therefore, for Reynolds numbers below about 78 (which marks the cutoff point for the low velocity Reynolds number correlation used in the spray model), the following variable transformation is used to make the integration smoother:

$$m^* = m^{1.04/0.87} \tag{2.4}$$

The ODE solver determines the final value of m* and then HECTR calculates the final value of m from this value.

Once the mass and temperature of the drops reaching the bottom of a compartment are known, the total mass- and heat-transfer rates to the compartment atmosphere are calculated.

$$m_e = (m_0 - m_f)\,DFR \tag{2.5}$$

$$\frac{dq}{dt} = -\, m_0 C_{PL}(T_f - T_0) + (m_0 - m_f)(h_{fg} + C_{PV}[T_g - T_f])\ DFR \tag{2.6}$$

where m_e = mass evaporated (kg/s)

m_0 = initial droplet mass (kg)

m_f = final droplet mass (kg)

DFR = droplet flow rate (drops/s)

$\frac{dq}{dt}$ = heat transfer to gas (W)

T_0 = initial droplet temperature (K)

T_f = final droplet temperature (K)

T_g = compartment gas temperature (K)

C_{PL} = liquid specific heat (J/kg-K)

C_{PV} = vapor specific heat (J/kg-K)

h_{fg} = heat of vaporization (J/kg)

The above equations are summed over the number of drop sizes. Any number of drop sizes can be treated with HECTR, however treating more than two drop sizes requires changing a PARAMETER statement in HECTR. Generally, two drop sizes are sufficient to produce reasonable results.

2.1.3 Spray Model for Pure Steam Atmospheres

The spray model discussed in the previous section fails when the steam mole fraction becomes sufficiently high that air-steam diffusion is no longer the dominant process. Early calculations for N Reactor resulted in steam mole fractions very close to 1.0 during the initial blowdown from a large break. Therefore, it was necessary to add a model to deal with this situation. A relatively simple model has been added that assumes the drops reach thermal equilibrium and allows appropriate conservation of mass and energy.

The spray drops are assumed to reach a final temperature equal to the saturation temperature corresponding to the partial pressure of steam in the compartment (T_{sat}). The change in droplet mass is then calculated from:

$$m_f - m_0 = \frac{m_0 C_{PL}(T_{sat} - T_0)}{h_{fg} + C_{PV}(T_g - T_{sat})} \qquad (2.7)$$

where the variables are those defined previously. Once the final mass, m_f, and temperature, T_{sat}, are calculated, then the overall heat and mass transfer rates are determined as described in the previous section. This model should be reasonably valid for situations where the steam temperatures are not sufficiently different from the drop temperatures that sensible heat transfer becomes large relative to latent heat transfer and the drop fall heights are more than a few meters so that the equilibrium assumptions are valid.

Once the final droplet mass is calculated, HECTR chooses between the air-steam diffusion model and the pure steam model. If the mole fraction of steam is less than or equal to 0.95, HECTR will always choose the diffusion model, and if the mole fraction of steam is greater than 0.999, HECTR will always choose the pure steam model. Between these values, HECTR will choose the model that yields the least amount of either condensation or evaporation, whichever is occurring. The diffusion model will yield less mass transfer for low steam concentrations. As the steam mole fraction approaches 1.0, then due to the effect on B in Equations 2.1 and 2.2, the model blows up. HECTR will then switch to the pure steam model. For additional insights regarding the use of the spray model, refer to Section 3.10 of Reference 2.

2.2 Flow Junctions

This section describes the types of junctions available to model the flow between compartments. For HECTR version 1.5N, an additional type of flow junction was added which models the more complicated valve logic used at N reactor. This section describes all of the flow junction options and is a replacement to Section A.2.1 of Reference 2.

Gases can be transferred between compartments because of flow through flow junctions, fans, or suppression pool vents. Fans and suppression pool vent flows are discussed in Sections A.2.2 and A.2.10 of Reference 2, respectively. Seven types of flow junctions are included in HECTR:

1. Two-way flow through an orifice
2. One-way flow through an orifice (check valve)

3. One-way flow through a variable area orifice (door)

4. Flow through drains in an ice-condenser containment

5. Flow through blowout panels

6. Flow through junctions that may become flooded because of a sump filling with water

7. Flow through valve type junctions where the flow area is controlled by trips and tables

Note that two-way flow does not mean that the flow can be going in both directions during the same timestep, but rather that the flow direction can freely change from one timestep to the next. The most common junction is the first type. The flows are determined according to Eq. A-5a in Reference 2, with user-specified values for flow area, flow resistance, and the ratio of the inertial length to the flow area (see Section A.1.1 of Reference 2). The second type of flow junction is similar to the first, except that flow is allowed in one direction only. The junction is assumed to be fully open as soon as the flow begins and to be closed as soon as the flow attempts to reverse.

The third type of flow junction allows the flow area to vary as a function of the differential pressure between compartments. This type of junction is used for modeling ice-condenser doors. The model was taken with only minor changes from Reference 12. A minimum differential pressure is specified that must be exceeded before the junction area will be allowed to increase beyond its minimum value, A_{min} (usually set to zero). Once the junction is open, the flow area is determined from the following expressions:

$$\frac{A}{A_0} = \frac{1.0 - \cos\theta}{1.0 - \cos\theta_0} \qquad (2.8)$$

and

$$\frac{\theta}{\theta_0} = \frac{\Delta P \cos\theta}{\Delta P_0 \cos\theta_0} \qquad (2.9)$$

where

A = flow area (m^2)

A_0 = fully open flow area (m^2)

ΔP = differential pressure across the junction minus the minimum pressure to open (Pa)

P_0 = differential pressure to hold the junction fully open (Pa)

θ = door opening angle (radians)

θ_0 = fully open door angle (radians)

A_0, ΔP_0, θ_0, and the minimum pressure to open the junction are user inputs.

The door flow area is very sensitive to small changes in pressure, and thus, the flows through the doors can vary dramatically from one timestep to the next, causing some numerical problems for HECTR. To alleviate these problems, some artificial smoothing is employed in the door model. The flow area used in the calculation is determined from

$$A_{new} = \begin{cases} 0.8A_{old} + 0.2A, & \text{for } A > A_{min} \\ 0.5A_{old} + 0.5A, & \text{for } A \leq A_{min} \end{cases} \qquad (2.10)$$

where A_{old} is the area used in the previous timestep, and A is the value determined from Eq. 2.8.

HECTR includes a special type of junction for floor drains that exist in ice-condenser containments. These drains allow water from the sprays to drain from the upper compartment to the lower compartment sump. HECTR models the drains as normal two-way flow junctions, but includes logic for closing the drains under certain conditions. HECTR will close the drains whenever the sprays are initiated or the lower compartment sump volume exceeds a user-specified value, such that the bottom of the drains would be covered.

Blowout panels can be modeled using the fifth type of junction. The flow area for this type of junction increases abruptly from 0 to a user-specified value when the pressure differential across the junction in the positive flow direction ("from" compartment minus "to" compartment) exceeds a second user-specified value. The junction flow area remains at this value for the rest of the calculation, even if the pressure differential is reduced. Note that the panels will <u>not</u> blow out if the specified pressure differential is exceeded in the negative flow direction.

Flow paths that become blocked as the water level in a sump rises can be modeled with the sixth type of flow junction. For this type of junction, the flow area is assumed to vary linearly between the fully open area and zero as the volume in a specified sump increases between specified values for the bottom and top of the junction. If the sump volume is less than the value corresponding to the bottom of the junction, the junction is fully open, and if the sump volume is greater than the value corresponding to the top, the junction is completely closed. This type of junction can also include a blowout panel. However, the panel is only allowed to blow out if the sump volume is less than the value corresponding to the bottom of the junction. If the sump volume is greater than this value, the panel is assumed to remain in place, even if the pressure difference exceeds the specified value. If the panels have blown out, then the flow area will be reduced as the sump volume increases between the values for the bottom and top of the junction.

To model the opening and closing of valves at N reactor, a seventh type of junction was added. The flow area for these "valve" junctions is controlled by user-defined trips and tables (See discussion of trips and tables in Section 2.4). The user specifies trips which must be satisfied to trigger opening and closing the valve. The opening (or closing) rates following the trip are controlled by opening (or closing) tables. The independent variable in the tables can be either differential pressure across the junction or elapsed time since the trip became true. A third trip must also be specified for "blowing open" the junction. If this trip becomes true, the flow area will remain fixed at a user-specified value for the remainder of the calculation. The example in Section 6 should help clarify the capabilities of valve type junctions.

Under certain conditions, the HECTR flow equations must be modified. In particular, if a check valve is closing, then an explicit expression is used for the flow equation to force the flow to zero at the end of the timestep. This is accomplished by setting the terms $\partial \dot{F}_1/\partial N$, $\partial \dot{F}_1/\partial E$, and $\partial \dot{F}_1/\partial F$ in the matrix A to zero and using the following expression for the corresponding term in the vector b.

$$\frac{dF_1}{dt} = \frac{-F_1}{\Delta t} \tag{2.11}$$

Flow junction velocities are not allowed to exceed sonic flow velocities. A basic HECTR assumption is that all flows are of low Mach number. Nevertheless, it is possible for the predicted flow velocities to be equal to or above the speed of sound. In such a case, the timestep is repeated using an explicit formulation similar to that discussed above. However, for this case, the flow is forced to the speed of sound, rather than to zero. The same terms in the A matrix are set to zero for this case, but the flow derivative expression used in the vector $\bar{b}$ is

$$\frac{dF_l}{dt} = \frac{F_s - F_l}{\Delta t}\ ,\ \text{for } F_l \geq 0 \tag{2.12}$$

$$= \frac{-F_s - F_l}{\Delta t}\ ,\ \text{for } F_l < 0$$

where F_s is the volumetric flow rate through the junction at sonic conditions.

If the flow at a junction reverses direction during a timestep, the mass and energy conservation equations must be modified. This is necessary because HECTR uses a donor formulation for the mass and energy equations (i.e., gases that flow between two compartments are assumed to be at the conditions of the upstream [donor] compartment). If the flow reverses during a timestep, the donor compartment also changes. Because of the implicit formulation that is used in HECTR, conditions of the donor compartment at the end of the timestep can be used during the entire timestep to give results that are equivalent to subdividing the timestep and using the appropriate donor compartment when calculating each part of the timestep. Thus, if the flow reverses during a timestep, HECTR repeats the timestep using the conditions of the new donor compartment when calculating the flow terms in the A matrix and b vector for the mass and energy equations. Flow reversals at containment leaks are treated similarly.

2.3 Containment Leakage Model

This section describes the containment leakage model. For HECTR version 1.5N, additional types of containment leaks were added to model the more complicated valve logic used at N reactor. This section describes all of the containment leakage options and is a replacement to Section A.2.13 of Reference 2.

HECTR includes models for three types of containment leakage: leakage following a pressure dependent curve, leakage following a temperature dependent curve, and gross containment failure. When more than one of these types of leakage is specified for a single leak, the leakage area is calculated as the sum of the leakage areas from the individual models. The flow equations for containment leakage were listed in Section A.1.1 of Reference 2. This section describes the methods used to calculate the leakage area.

The gross containment failure type of leakage was originally intended to model a break in containment, such that the leak area was set to a fixed value if a specified variable exceeded a threshold. For HECTR version 1.5N, this option was expanded to include flow through paths to the environment that could reclose.

2.3.1 Temperature Dependent Leakage

The temperature dependent leakage model prescribes the leakage area as a specified function of temperature and time. A threshold temperature, TEST, is defined such that when the compartment atmospheric temperature reaches or exceeds TEST, a timer is set which is compared to a "soak period" (T1) and a "seal degradation period" (T2). During the "soak period", the leak area is maintained at the initial area (A1), and during the period of seal degradation, the leakage area is increased linearly to the final leak area, A2. This modeling is an attempt to describe the thermal degradation of valve seals under extreme containment thermal conditions. The parameters TEST, T1, T2, A1, and A2 are input by the user; multiple sets of these parameters can be specified to allow different criteria to be used in various compartments during a calculation.

2.3.2 Pressure Dependent Leakage

The pressure dependent leakage model consists of user-defined tables of pressure induced leak areas, ALK(J), as a function of the differential pressure, DPL(J). The user has two choices for calculating the differential pressure: 1) leaking compartment pressure minus the ambient pressure or 2) differential pressure across the leak (ambient pressure minus leaking compartment pressure with gravity head adjustments to the leak elevation for both the ambient and the leaking compartment). Multiple tables can be defined to allow different pressure dependent leakage characteristics to be modeled in various leakage paths for a calculation. An input option provides for the calculation of hysteresis effects if desired. However, if the second option for calculating differential pressure is chosen, the user can not include hysteresis; the same curve must be used for opening and closing the leakage.

The pressure dependent leakage area for increasing pressure is calculated by linear interpolation of the input tables. If the hysteresis option is not selected, the pressure dependent leak area is maintained at the maximum value previously obtained if the pressure decreases below the corresponding maximum pressure.

When the hysteresis option is selected, the code will calculate a leak area that follows a different path as the pressure decreases than it did as the pressure was increasing. When modeling hysteresis, a set of factors, FLK(J), for each pressure dependent curve for which hysteresis has been selected must be supplied in the input. These factors are multipliers which convert the ascending curve defined in the ALK array into the descending or hysteresis curve. The factors are calculated according to the following equation:

$$FLK(I) = \begin{cases} \dfrac{\left(\dfrac{AHY(I)}{ALK(I)} - 1\right)[ALK(IND) - ALK(1)]}{[ALK(IND)-ALK(I)]}, & \text{for } I \leq IND \\ = 0., \text{ for } I \geq IND \text{ (Note that this result (0) will give } AHY(I) = ALK(I)) \end{cases} \quad (2.13)$$

where

IND = point on the original curve to which the hysteresis curve is indexed

AHY(I) = the leakage areas for the descending curve (m^2)

The area obtained by solving Eq. 2.13 for AHY is then multiplied by the ratio AMAX/ALK(IND) to yield the containment leak area used in the calculation (where AMAX is the maximum area obtained before the depressurization phase commenced).

It should also be noted that the table of area versus pressure differential must contain 10 entries. If sufficient values are not available, the table should be filled out with suitably interpolated values.

2.3.3 Containment Failure Model

Three general types of options are available for the gross containment failure model: failure based on a variable exceeding a specified threshold, vacuum breaker type inflow, or leakage area controlled by trips and tables.

For the first option, failure can be predicated on time, pressure, or temperature. The user can specify that the leak either remains permanently open (after failure) or recloses following an area vs time curve after a timer elapses. The timer begins when the pressure in a specified compartment (which can be different from the leaking compartment) exceeds a threshold. For leaks that reclose, the user can specify either 1) that the leak must remain permanently closed following failure and reclosing or 2) that the leak can reopen if the failure criterion is again exceeded in the calculation.

The second option models vacuum breakers between a compartment and the environment. If the differential pressure across the leak (environment minus compartment) exceeds a threshold, the vacuum breaker is fully open; otherwise, it is fully closed.

The third option uses trips and tables to control the leakage area. Trips are specified to trigger opening and closing of the leak and tables are specified to define the opening and closing rates. The tables define the fraction open of the leak and can be based on either differential pressure across the leak or time since the opening/closing began.

2.4 Trips and Tables

To provide a more flexible treatment of valves than was available in HECTR version 1.5, new options were added for junctions and containment leaks that reference trips and tables to control the flow area. This section describes the options available for trips and summarizes the use of tables.

2.4.1 Trips

The following types of trips are available in HECTR version 1.5 N:

1 Variable versus threshold
  - compartment pressure
  - differential pressure across junction
  - compartment temperature
  - time

2 Combination of other trips

3 Test on time since desired trip became TRUE.

Several tests can be combined to form a single trip, as long as each test is of the same type. For example, a trip can test for compartment pressures exceeding different thresholds in several different compartments, but a single trip can not test for a compartment pressure greater than a threshold and a compartment temperature greater than a threshold. This second case would have to be handled with three trips: one for the pressure test, a second for the temperature test, and a third to combine the results into a single trip using a type 2 trip. When multiple tests are specified for a trip, the user also specifies the number of these tests that must be TRUE for the trip to be TRUE.

For the variable tests, both "greater than" and "less than" tests can be performed, but within a given trip, all tests must be either "greater than" or "less than" (eg., a single trip can not test for pressure in compartment 1 greater than a value and pressure in compartment 2 less than a second value. This must be handled with 3 trips: one for each of the pressure tests and a third to combine the tests into a single trip). Similarly, for the second type of trip, the referenced trips can be compared against either TRUE or FALSE.

Finally, a flag can be set which either locks a trip TRUE if it becomes TRUE or allows the trip to be reset to FALSE if the conditions are no longer satisfied.

2.4.2 Tables

Some of the new junction and leak options added to HECTR version 1.5N reference tables to determine the fraction open. By referencing tables rather than repeating the input for each junction or leak that uses the same curve, the input is simplified. The tables are merely sets of x-y pairs. The flow junction and containment leak models assign a meaning to the x and y values.

2.5 Miscellaneous Upgrades to HECTR Version 1.5

A number of minor changes were made to HECTR to allow execution of different size problems and to eliminate some minor shortcomings in the code. Those changes are described in this section.

2.5.1 Condensation Weighting Factor Control

It is possible to encounter situations where the mass transfer to a surface occurs alternately by condensation and evaporation. While this rarely occurs, it can cause some numerical difficulty if encountered. To alleviate this problem, a weighting factor can be used relating the current values of the heat and mass flux to the values from the previous timestep. That is

$$V = WF * Vnew + (1 - WF) * Vold \tag{2.14}$$

where

V = value to be used in the calculation

WF = weighting factor

$$= \begin{cases} 1., & \text{for steam void fraction} \le XWFHS \\ WFHS, & \text{for steam void fraction} > XWFHS \end{cases}$$

$Vnew$ = value calculated based on current conditions

$Vold$ = value from previous timestep

In HECTR Version 1.5, WFHS was set to 0.1 and XWFHS was set to 0.7. To allow greater flexibility, WFHS and XWFHS have been added as NAMELIST type variable in HECTR Version 1.5N. The default valves are those used in HECTR 1.5, but they can be reset as described in Section 3.2.3.10.4.

2.5.2 Changes to PARAMETER Statements in HECTR

This section describes the changes to the HECTR PARAMETER statements and replaces Section B.2.7 in Reference 2.

PARAMETER statements are used in HECTR primarily to define array sizes. All the arrays in HECTR Version 1.5N have been dimensioned large enough to run the sample problem described in Chapter 5 and the calculations performed in Reference 3.

The arrays have been dimensioned to relatively large default values because of the type of computing systems available at Sandia. When using computers that do not have virtual memory, the default parameter sizes will probably need to be reduced. To change the size of all the arrays in HECTR that are concerned with a certain item, it is necessary only to modify all the corresponding PARAMETER statements. For example, the maximum number of compartments allowed by HECTR can be decreased from 50 to 10 by changing "NC = 50" to "NC = 10" in all the PARAMETER statements in HECTR where NC is set. There is a set of PARAMETER statements near the top of most program units. Each set is exactly alike, so that this modification can be done simply by a global substitution. (Note: If HECTR is stored using CDC UPDATE or a similar program, then changing values in parameter statements can be accomplished most conveniently when the PARAMETER statements are stored in a COMDECK.)

The symbolic names of constants set in PARAMETER statements in HECTR are listed below, along with the values to which they are set and a short description of what each one represents. All of the symbolic names can be set to any positive value desired by the user (as long as HECTR still fits in the computer's memory) with three exceptions--NG and NNV cannot be changed without also changing other coding in HECTR, and NDE is defined in terms of NC, NG, NJ, and NV and will automatically compensate for changes in any of these values.

N2C	=	10	(maximum number of second-level spray actuation criteria per spray train)
NBO	=	5	(maximum number of blowout panel junctions)
NC	=	65	(maximum number of compartments)
NCB	=	10	(maximum number of continuous burning compartments)
NCRC	=	10	(maximum number of entries per second-level spray train actuation criteria)
NCRS	=	5	(maximum number of top-level actuation criteria per spray train)
ND	=	8	(maximum number of inertial valve flow junctions [doors])
NDE	=	(NG+1)*NC +NJ+NV	(maximum number of simultaneous ordinary differential equations to be solved each flow timestep - these are the equations expressing conservation of mass, energy, and momentum)
NDR	=	2	(maximum number of drains)
NDS	=	2	(maximum number of spray drop sizes)
NESC	=	5	(maximum number of compartments with energy sources)
NF	=	30	(maximum number of fan paths)
NFLD	=	10	(maximum number of flooded type junctions)

NGET	= NS+13	(maximum number of entries per input record)
NICE	= 16	(maximum number of ice compartments in an ice condenser)
NJ	= NJF + NL	(maximum number of flow junctions plus containment leaks)
NJF	= 145	(maximum number of flow junctions)
NL	= 30	(maximum number of containment leaks)
NLAYER	= 3	(maximum number of layers per slab surface)
NLKVAL	= 5	(maximum number of valve type leaks)
NNV	= 69	(number of pseudo-NAMELIST variables)
NP	= 5	(maximum number or pressure-dependent curves for containment leakage)
NPTAB	= 5	(maximum number of pairs per table)
NS	= 145	(maximum number of surfaces)
NSC	= 15	(maximum number of compartments in which sprays originate per spray train)
NSE	= 2000	(maximum number of source-term table entries for each gas)
NSMC	= 25	(maximum number of compartments containing sumps)
NSMP	= 10	(maximum number of sumps)
NSTR	= 4	(maximum number of independent spray trains)
NSVEN	= 7	(maximum number of steam vent type leaks)
NSVPTS	= 5	(maximum number of pairs in steam vent leak closing tables)
NT	= 5	(maximum number of temperature-dependent curves for containment leakage)
NTABL	= 10	(maximum number of tables)
NTRIP	= 30	(maximum number of trips)
NTTST	= 10	(maximum number of tests per trip)
NV	= 3	(maximum number of suppression pool vents)
NVALV	= 20	(maximum number of valve type junctions)
NWD	= 5	(maximum number of both drywell and wetwell compartments)
NWN	= 5000	(maximum number of wall nodes = total for all slab surfaces)
NXXFC	= 10	(maximum number of fan cooler paths)
NXXXFC	= 5	(maximum number of fan cooler assemblies)

2.5.3 Changes to PARAMETER Statements in ACHILES

This section describes the changes to the ACHILES PARAMETER statements and replaces Section B.3.7 in Reference 2.

PARAMETER statements are used in ACHILES to define array sizes. All the arrays in ACHILES have been dimensioned large enough to run the sample problem described in Chapter 5 and the calculations presented in Reference 3. Like HECTR (see Section 2.5.1), the arrays in ACHILES have been dimensioned to relatively large values. Users at other installations may need to decrease the sizes of some of the areas due to computer memory limitations. To change the size of all the arrays in ACHILES that are concerned with a certain item, it is necessary only to modify all the corresponding PARAMETER statements. For example, the maximum number of data points plotted per graph can be increased from 500 to 1000 by changing "NPTS = 500" to "NPTS = 1000" in all the PARAMETER statements in ACHILES where NPTS is set. There is a set of PARAMETER statements near the top of most program units. Each set is exactly alike, so that this modification can be done simply by a global substitution.

The symbolic names of constants set in PARAMETER statements in ACHILES are listed below, along with the values to which they are set and a short description of what each one represents. All of the symbolic constants can be set to any value desired by the user as long as three conditions are met: (1) ACHILES must fit in the computer's memory, (2) the value of the constant must be positive (an array cannot be dimensioned to zero or less), and (3) if the symbolic constant is NC, NF, NG, NJ, NS, NV, NSC, or NSMP, then its value should be greater than or equal to that of the HECTR symbolic constant of the same name. If the user is running on a computer with virtual memory, we recommend increasing the value of NPTS to at least 1000, as the typical resolution of a good quality plotting device is around this number. Finally, it should be noted that NNV cannot be changed and NCOLS cannot be decreased without also changing other coding in ACHILES.

NC	=	75	(maximum number of compartments)
NCB	=	5	(maximum number of continuous burning compartments)
NCOLS	=	6	(maximum number of graphs that can be produced in one pass of data reads)
NF	=	30	(maximum number of fan paths)
NFC	=	10	(maximum number of fan cooler paths)
NG	=	6	(number of gas species: H_2O, N_2, O_2 and H_2)
NICE	=	16	(maximum number of ice compartments in an ice condenser)
NJ	=	175	(maximum number of flow junctions)
NL	=	30	(maximum number of containment leaks)
NNV	=	40	(number of pseudo-NAMELIST variables)
NPTS	=	500	(maximum number of data points plotted per graph)
NS	=	175	(maximum number of surfaces)
NSC	=	25	(maximum number of compartments in which sprays originate)
NSMP	=	20	(maximum number of sumps)
NST	=	5	(maximum number of independent spray trains)
NV	=	3	(maximum number of suppression pool vents)
NWD	=	5	(maximum number of drywell or wetwell compartments)

2.5.4 HECTR Program Structure

Appendix B of Reference 2 describes the HECTR program structure in detail, including the functions and locations of subroutines and the locations of common blocks. In Version 1.5N, the overall code structure and subroutine functions are unchanged. Some changes were made to the variables located in particular common blocks and also some common blocks are now present in different subroutines than before. In particular, common block NEJUN has been added to subroutines INITAL, CLEAK, INIOUT, and OUTF; common block SPRAYE has been added to subroutines NAMLST and CONTRL; and common block GEOM has been added to subroutine OUTF.

3. REVISED INPUT INSTRUCTIONS

3.1 Introduction

This chapter describes the input required for HECTR. For convenience, this chapter is a complete description of the input and is a replacement to Chapter 4 of Reference 2. This input is identical to that described in Reference 2, except in the areas of spray input and junction and leak logic. A vertical line in the right margin marks the portions of input that are different from Reference 2.

Input is required for both the main program, HECTR, and the program that processes the output, ACHILES. Input to HECTR can be provided in a single file or in two files: one describing the problem geometry and one describing the initial conditions and accident scenario. These files are combined with another file to control ACHILES, as described in Appendix C of Reference 2.

Real, integer, and alphanumeric data are included in the input. These data types are identified below by the symbols [R], [I], and [A], respectively. A fourth type, symbolized by [L] (for logical), can have only the alphanumeric values TRUE or FALSE. All real and integer values are read in free format. This means that the values can be separated by blanks or commas with blanks interspersed freely (note that no other character, such as a tab, is a valid separator). Also, the values may have replication factors such that 3*2.7 (equivalent to 2.7 2.7 2.7) is a valid input.

In the input description provided below, three angle brackets (>>>) are used as delimiters to indicate the beginning of a new data record. Variables listed between two sets of these delimiters may be placed either all on one line or on as many separate lines as desired (all of these variables will correspond to a single read). The names of the variables are those actually used by HECTR or ACHILES.

A dollar sign ($) in column 1 signifies the end of a table input section when appropriate--the rest of the line may be used as a comment. The beginning of a table input section is indicated in the variable description below by the notation "while column 1 not = '$'". The variables listed below this statement (indented in the text), and before the matching "end while", form the table entries. A table can have an indefinite number of entries (including no entries). To create an empty table, it is necessary only to enter a single line containing a dollar sign in column 1. The notation, "for i=1, Number of Entries", indicates a loop on i over the indented variables following this statement and preceding the matching "end for". If the "Number of Entries" is zero, then the loop and the variables within it should be ignored (i.e., do not input any values). The notation "if condition then" indicates that the indented variables listed after this statement and above the matching "end if" will be read if the condition is true. Any text following an exclamation mark (!) (except within a line of alphanumeric input) is treated as a comment and thus ignored. Any lower case letters found in the input will be converted to upper case. The only exception is lower case letters in comments, which will be echoed unchanged. The sample problem presented in Chapter 5 that should help clarify the input description that follows.

3.1.1 NAMELIST-Type Input

Some input to HECTR is in a pseudo-NAMELIST-type format. Default values are provided for all such variables. The variables that can be changed using NAMELIST-type input are listed in Sections 3.2.1, 3.2.3, and 3.3.1. Variables are assigned new values (one per line of input) using the following format:

```
varble = <value>
```

where the variable name is 6 characters or less in length. Blanks can be interspersed fairly freely throughout the entry. <value> can be either a number (real or integer) or a character string, depending on the variable type. Variable types with alphanumeric values include status variables (such as whether the sprays are on, off, or automatic), specification variables (e.g., the type of computer being employed), and logical variables (which can only have character string values of either "TRUE" or "FALSE"). If the variable in the above expression is an array, then all elements in the array will be set equal to <value>. To assign a value to a single array element, use the following format instead of the format shown above:

```
varble(i)=<value>
```

where the i is an integer subscript. The NAMELIST-type input is terminated with a dollar sign ($) placed in column 1. Lines that begin with an exclamation mark are always treated as comments as is any text following an exclamation mark located elsewhere in an entry line. For example, a typical set of input might look like

```
! Namlst input
XHMNIG=.1          ! Set the ignition limit in all
                   ! compartments to 10%
BURNT(2) = 1.      ! Set the burn time in Compartment 2 to 1
                   ! second
FANS =ON
$ END OF NAMLST INPUT
```

3.1.2 Special Notes on Sump Input

Each sump in a containment must be identified by a unique number (specified in the Sump Data section) that lies between one and the total number of sumps being modeled, inclusive. For each sump, at least one heat-transfer surface must be listed in the Surface Data section (A heat-transfer surface is identified as a surface of a sump through the STYPE and ISS input variables). The heat-transfer surfaces for a sump can be located in different compartments, but the temperatures of all surfaces of a given sump will be equal (the initial temperatures of all surfaces of a given sump <u>must</u> be equal). The initial masses input for each of the surfaces of a sump are summed to give the total initial water mass of the sump. Each compartment can contain an arbitrary number of sumps (including no sumps). The relationship between compartment volume (specified in the Compartment Data section), sump capacity (specified in the Sump Data section), and the initial mass of water in the sump (specified in the Surface Data section) for the simple case of a single sump in a compartment is illustrated in Figure 3.1. The variable names shown in parentheses are those that appear later in Section 3.2.3, except for the density, ρ, which is calculated internally. The user should be careful to specify these values such that a compartment volume is not reduced to 0 because of sumps filling excessively.

3.1.3 Special Notes on Ice-Condenser Input (See also Section 6.2 of Reference 2)

HECTR automatically generates compartments, surfaces, and junctions for the ice-bed region based on information input in the Ice-Condenser Data section. However, the lower and upper plena must be entered as a set of regular compartments. The flow junctions entering and exiting the ice-bed region must also be entered by the user. All references to the number of compartments (NCOMPS) or surfaces (NSURFS) in the HECTR input sections refer to the total number of compartments or surfaces directly input by the user; the compartments and surfaces generated internally by HECTR should not be included when calculating NCOMPS or NSURFS. Note that, in the ACHILES input section, asking for all compartments, flow junctions, or surfaces <u>WILL</u> include the HECTR generated compartments, flow junctions, and surfaces.

3.1.4 Special Notes on Mark III BWR Input (See also Section 6.3 of Reference 2)

When modelling the suppression pool for a Mark III containment, input is required in three sections: sump data, heat transfer surface data, and suppression pool data. Three sumps must be entered in the sump input section to represent

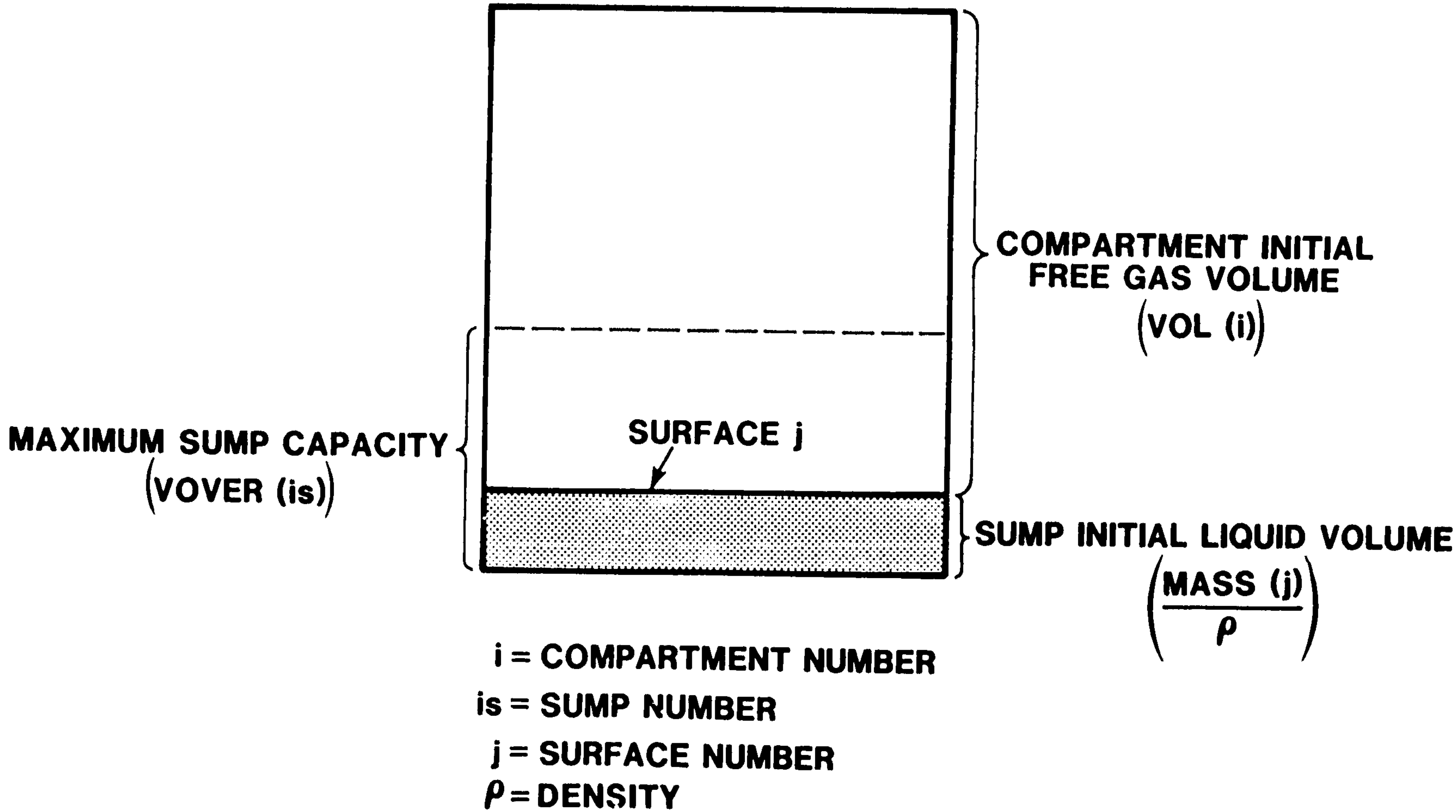


Figure 3.1. Relationship between Compartment Volume, Sump Capacity, and Sump Liquid Mass in HECTR

the suppression pool, upper pool, and drywell pool. As for any of the other sumps, the user must also specify heat transfer surfaces for each sump in the heat transfer surface input section. Further parameters for the suppression pool must be specified in the Suppression Pool Data section.

3.2 Input File(s) for HECTR

The HECTR input file consists of three major sections. These are the initial NAMELIST-type input in which the computing environment is defined, a description of the problem geometry, and a description of the initial conditions and the accident scenario.

3.2.1 Initial NAMELIST-Type Input

The form of this input was described previously. This data is read from Unit 5. Default values are provided for all of the variables in this section (as shown by the quantities within the angle brackets), and new values need be assigned only for those variables that the user wishes to change. This section of input is terminated with a dollar sign ($) placed in column 1. Normally, this first pseudo-NAMELIST input is used to define the HECTR input/output units and to set the input echoing flag. These variables can be set individually; however, a shortcut is sometimes possible. A variable exists (CMPUTR) that defines the type of computer on which HECTR is running and, depending on the computer type, causes certain default actions to be taken. Basically, input is echoed, and the input units are set to 5, if HECTR is being run in a noninteractive mode (as often will be the case on a CDC [CYBER] or CRAY computer). Input is not echoed and the input units are set differently on a VAX where HECTR will typically be run interactively. It is very important to note that while these actions are desirable in the computing environment available at SNLA, they may not be optimal at other installations. If these actions are not desirable, the CMPUTR variable should be ignored, and the units and flags should be set individually to the values desired by the user. If setting CMPUTR produces the appropriate results, this section of input can be considerably simplified. For example, when running on a VAX, this section of input will consist simply of a dollar sign in column 1 (since the VAX is the default computer type); on a CRAY this input will be

```
CMPUTR=CRAY
$
```

In addition, the initial NAMELIST input can be used to expand the number of gases treated in HECTR, change the default number of compartments used to model an ice condenser, or to eliminate the radiative heat transfer calculations. This is done using the NAMELIST variables COCO2, NICEC, NICEX and RAD.

By default, HECTR does not include carbon monoxide or carbon dioxide in a simulation. To include these gases the variable COCO2 must be set to TRUE in the initial NAMELIST call. When COCO2 is set to TRUE, initial conditions and source tables must be input for all 6 gases (variables in arrays dimensioned to "number of gases" in the following sections), whereas if COCO2 remains at the default of FALSE, information must only be input for 4 gases.

Radiative heat transfer is included in a HECTR simulation by default. However, the radiative heat transfer calculations can be bypassed by setting the NAMELIST variable RAD to FALSE in either the initial NAMELIST call or in the second NAMELIST call. If RAD is reset to FALSE in the initial NAMELIST call, the beam length and view factor input must not be included in the input deck. If RAD is <u>not</u> overridden in the initial NAMELIST call, but is then reset to FALSE in the second NAMELIST call (see Section 3.2.3.8), the view factor and beam length data must be input, but will not be used in the simulation. This second case allows the same input deck to be used for simulations without radiative heat transfer as is used for simulations that include radiative heat transfer with only the minor change of setting RAD to FALSE in the second NAMELIST call.

By default, HECTR generates a single column of four vertically stacked compartments to model the ice-bed region of an ice condenser. The variable NICEC can be reset in the initial NAMELIST call if more compartments are desired in a single column. The variable NICEX can be reset if the user wishes to divide the ice condenser circumferentially into multiple columns of vertically stacked compartments.

>>>
3.2.1.1 Input Control Variables

BATCH [L] - <Default = FALSE>
If TRUE, then all input will be echoed. This will normally be desirable when running HECTR in batch (noninteractive) mode and undesirable when running HECTR interactively. See also CMPUTR.

CMPUTR [A] - <Default = VAX>
Type of computer on which HECTR is running. The effects of the possible values of this variable are

CDC	sets BATCH to TRUE and sets URD and UIC to 5
CYBER	same as for CDC
CRAY	same as for CDC
VAX	sets BATCH to FALSE and sets URD and UIC to 4

These actions are desirable in the computing environment available at SNLA, but they may not be optimal at other installations.

INPCHK [L] - <Default = FALSE>
In a future version of HECTR, this will cause (if TRUE) the validity of HECTR input to be checked.

UMI [I] - <Default = 1>
The unit from which external (MARCH) input is read.

URD [I] - <Default = 4>
The unit from which the reactor data (Section 3.2.2) is read. See also CMPUTR.

UIC [I] - <Default = 4>
The unit from which the initial conditions and the accident scenario (Section 3.2.3) are read. See also CMPUTR.

3.2.1.2 Output Control Variables

See Section 5.2.3.1 of Reference 2 and Chapter 4 of this report for discussions of the output units described below.

UOM [I] - <Default = 6>
The unit to which output messages produced by HECTR are written.

UOH [I] - <Default = 7>
The unit to which the output of major variables defined on heat-transfer timesteps is written (in unformatted WRITEs). ACHILES processes the data written to this unit to produce tables and graphs. The ACHILES input unit corresponding to UOH is UHD (which defaults to 7). If UOH is set to zero, then no timestep information of any kind will be written by HECTR (UOF and UOA will also be set to zero).

UOF [I] - <Default = 8>
The unit to which the output of major variables defined on flow timesteps is written (in unformatted WRITEs). ACHILES processes the data written to this unit to produce tables and graphs. The ACHILES input unit corresponding to UOF is UHF (which defaults to 8). If UOF is set to zero, then no flow timestep information will be written by HECTR.

UOA [I] - <Default = 0>
The unit to which the output of additional variables defined on heat-transfer timesteps is written (in unformatted WRITEs). ACHILES processes the data written to this unit to produce tables and graphs. The ACHILES input unit corresponding to UOA is UHA (which defaults to 9). If UOA is set to zero, then no additional heat-transfer timestep information will be written by HECTR. The information written with this unit is typically used for debugging or for other special interest purposes.

3.2.1.3 Miscellaneous Variables

NICEC [I] - <Default = 4>
The number of compartments which are automatically generated by HECTR for each vertically-stacked column of the ice bed region of an ice condenser. This number multiplied by NICEX (defined below) must be less than or equal to the value of the symbolic constant NICE set in PARAMETER statements in HECTR (see Chapter 2). See Section A.2.8 of Reference 2 for further information.

NICEX [I] - <Default = 1>
The number of vertically-stacked columns (for dividing the ice condenser circumferentially) which are automatically generated by HECTR. See discussion of NICEC above.

COCO2 [L] - <Default = FALSE>

If COCO2 is FALSE, carbon monoxide and carbon dioxide will not be included in the simulation and "number of gases" in the following input sections will be 4. If COCO2 is TRUE, the two additional gases will be included in the simulation, and "number of gases" will be 6.

RAD [L] - <Default = TRUE>
If RAD is TRUE, radiative heat transfer calculations will be performed. If RAD is FALSE, radiative heat transfer calculations will be bypassed. See discussion in introduction to section 3.2.1 for the effect of RAD on the required input of beam lengths and view factors.

Remember to enter a $ in column 1 at the end of the NAMELIST type input!

3.2.2 Problem Geometry

This data is read from unit URD (URD is defined in Section 3.2.1.1: Input Control Variables).

3.2.2.1 General

>>>
LTITLE [A] - A title of 37 characters or less used as a header for output. The last non-blank character must be a dollar sign ($).

for i=1,9
>>>
Any of the following lines of text may be blank, but all nine lines must be included. If the first nonblank character is a !, then that line will be considered a comment rather than one of the nine text line inputs.

TEXT(i) [A] - A line of 80 characters or less used for descriptive comments.

end for
>>>
NCOMPS [I] - Number of compartments. For an ice-condenser geometry, this number includes the lower and upper plenum compartments of the ice condenser but does not include the compartments in the ice-bed region.

3.2.2.2 Compartment Data

for i=1,"Number of Compartments" (see Section 3.1.3)

```
>>>
  COMPID(i)        [A] - A 72-character or less compartment
                         descriptor.

>>>
  VOL(i)           [R] - (cubic meters)
                         Initial free gas volume of compartment
                         i.

  Z(i)             [R] - (meters)
                         Compartment elevation.  Normally, this
                         is the elevation of the middle of the
                         compartment.  All compartments are
                         referenced to the same baseline eleva-
                         tion.

  CHRLEN(i)        [R] - (meters)
                         Characteristic length for flame propa-
                         gation for discrete burns.  The burn
                         time is calculated by dividing the
                         characteristic length by the flame
                         speed.  See Section 3.6 of Reference 2
                         for further information.

  NSURFC(i)        [I] - Number of heat-transfer surfaces in
                         compartment i.  This number may be
                         zero.

  ISV(i)           [I] - The number of the sump where water
                         condensed from the atmosphere of
                         compartment i due to subcooling (super-
                         saturation) is placed.  If this number
                         is zero, then the water produced from
                         subcooling in this compartment will
                         disappear from the system, and hence,
                         mass will not be conserved.

  ISSP(i)          [I] - The number of the sump where unevapor-
                         ated spray drops that reach the floor
                         of compartment i and are not carried
                         over into lower compartments are
                         placed.  If this number is zero, then
                         the unevaporated drops will disappear
                         from the system.

end for
```

3.2.2.3 Sump Data

If this simulation does not include sumps, then enter a $ in column 1 and skip the rest of this section of input.

while column 1 not = '$' (see Section 3.1.2)

>>>

is [I] - The number identifying the sump.

VOVER(is) [R] - (cubic meters) Capacity of the sump. When modeling Mark III suppression pools, this quantity indicates the holdup volume for the sump representing the drywell pool(corresponding to H_{DP} in Section A.2.10 of Reference 2). For the sump representing the suppression pool, this quantity must be entered, but will not be used by the code.

DUMPTO(is) [I] - The number of the sump into which any overflow from the current sump (is) is dumped. Overflow will occur if the sump volume exceeds the capacity (defined above). If this number is zero, then any water that overflows from this sump will disappear from the system. If the sump is specified to overflow into a second sump and the second sump is specified to overflow back into the first sump, then whenever the capacities of both sumps are exceeded, the two sumps will both fill up beyond their capacities, and the excess water will be divided between them by the ratio of the surface areas of the two sumps. Overflow between the suppression pool and drywell pool is accounted for internally by HECTR. Thus, this quantity will be ignored for sumps specified to be either the drywell pool or the suppression pool.

end while

3.2.2.4 Surface Data

Because the surfaces will be automatically numbered in the order that they are entered, the order of entry for individual surfaces is important. The radiative heat-transfer input (see Section 3.2.2.9) must be consistent with the surface-data numbering. Also, the surfaces entered in this section will be placed in compartments in the order in which they are entered, i.e., using the values for NSURFC(i) entered previously in

Section 3.2.2.2, the first NSURFC(1) surfaces will be placed in Compartment 1, the next NSURFC(2) surfaces will be placed in Compartment 2, etc. However, the sumps need not be entered in any particular order. The value of ISS(i) entered for each surface of a sump will indicate the proper sump number, i.e., for each sump, is, defined in Section 3.2.2.3 there must be at least one surface, i, entered below with STYPE(i) = 3 and ISS(i) = is.

The notation "Number of Surfaces" in this and all following "for" statements refers to the total number of surfaces in the containment excluding surfaces in the ice-bed region.

for i=1,"Number of Surfaces"   (see Section 3.1.3)

\>>>

SURFID(i)   [A] - A 72-character or less surface descriptor.

\>>>

STYPE(i)   [I] - Describes the type of surface. Enter

1 if the surface is a multi-layered slab
2 if the surface is a lumped mass
3 if the surface is a pool (a sump)

Surface types 4 and 5 define ice surfaces and ice-condenser walls, respectively. These two types are set up internally by HECTR.

MASS(i)   [R] - (kilograms)
Mass of lumped mass or sump surface. If surface i is the surface of a sump, then MASS(i) will be the portion of the initial liquid mass in the sump added by this surface. The total mass of liquid for a sump with several surfaces is obtained by summing the masses for each surface. This quantity must be entered but will be ignored if the surface is a slab (see above description of STYPE).

AREA(i)   [R] - (square meters)
Surface area used for heat transfer.

L(i)   [R] - (meters)
Characteristic length for convective heat transfer. See Section 3.8 of Reference 2 for further information.

CP(i)   [R] - (joules per kilogram per kelvin)

Specific heat of the surface. This quantity must be entered but will be ignored if the surface is not a lumped mass (STYPE = 2).

EMIS(i) [R] - Radiative emissivity of the surface.

ISS(i) [I] - If surface i is the surface of a sump, then ISS(i) will be the number of that sump. For all other types of surfaces, this value is the number of the sump where condensate that drains off the surface is placed. If this number iszero, then condensate runoff will dis- appear from the system.

if STYPE(i) = 1 then (the surface is a multilayered slab)
>>>

NUMLAY(i) [I] - Number of layers in the slab. <u>Note: An error has been reported on HECTR Version 1.5 when 2 or more layers are used. Therefore, only single layers should be modeled. This will be corrected in a future version of HECTR.</u>

for j=1,NUMLAY(i)
>>>

LAYTHK(j,i) [R] - (meters) Thickness of the jth layer. The layers are counted starting from the front side of the slab (layer number 1 receives the heat transfer directly from the compartment atmo- sphere).

LAYA(j,i) [R] - (square meters per second) Thermal diffusivity of the layer.

LAYK(j,i) [R] - (watts per meter per kelvin) Thermal conductivity of the layer.

end for
>>>

NUMEL(i) [I] - Number of elements in the slab heat- conduction model. The number of ele- ments must lie between 0 and 100 inclusive. If this value is zero, then the number of elements will be chosen automatically by HECTR. See Section 3.9 of Reference 2 for further information.

ELEXP(i) [R] - Element distribution exponent. Choosing a positive number less than 1 will result in a distribution of elements increasing in length as the back side of the slab is approached (where less resolution is normally needed than at the front surface in the heat-conduction model). If this number is zero, then HECTR will automatically choose an appropriate value. See Section 3.9 of Reference 2 for further information.

HCONV(i) [R] - (watts per square meter per kelvin) Convective heat-transfer coefficient for the back side of the slab. Set this value to 0 if the back side of the slab is to be insulated or to -1. if it is to have a constant temperature boundary condition.

TENV(i) [R] - (kelvins) Temperature of the environment on the back side of the slab. If the back side is to be insulated, then set this quantity to 0.

end if

end for

3.2.2.5 Containment Leakage Data

If this simulation does not include containment leakage, then enter a $ in column 1 and skip the rest of this section of input. See Chapter 2 for a further description of the input variables listed below.

>>>

NOL [I] - Number of containment leaks.

NOP [I] - Number of separate pressure-dependent leakage curves.

NOT [I] - Number of separate temperature-dependent leakage curves.

for i=1,NOL

>>>

NID(i) [I] - Compartment number in which this leak is located.

NTD(i) [I] - Number identifying temperature-dependent leakage curve to be used for this leak. (Input 0 if there is no temperature-dependent leakage for this leak).

NPD(i) [I] - Number identifying pressure-dependent leakage curve to be used for this leak. (Input 0 if there is no pressure-dependent leakage for this leak). If NPD(i) < 0, a differential pressure (atmosphere minus compartment, with gravity head adjustment) is used in the leak area calculation, rather than the compartment pressure; curve number -NPD(i) is used for the calculation.

NCF(i) [I] - Containment failure flag. Enter

0	for no gross failure
1	for failure at a specified time
2	for failure at a specified pressure
3	for failure at a specified temperature.
4	for a leak that opens instantaneously if the differential pressure across it (atmospheric - compartment, with gravity head adjustment) exceeds a set point, then recloses instantaneously if the differential pressure drops back below the set point.
5	for leak whose area is controlled by trips and tables
-1	for failure at specified time which recloses after a timer elapses.
-2	for failure at specified pressure which recloses after a timer elapses.
-3	for failure at specified temperature which recloses after a timer elapses.

TPT(i) [R] - (seconds, pascals, or kelvins) Containment failure criterion for the option chosen with NCF(i) (differential pressure that triggers the opening / closing for NCF(i) = 4).

AFL(i) [R] - (square meters)
Containment failure area.

ZJI(i) [R] - (meters)
Elevation of leak.

FLI(i) [R] - Flow loss coefficient for leak.

LAI(i) [R] - (1/meters)
The flow length through the leak divided by an effective flow area.

if NCF(i) = 5 then
>>>
In the following, ij is an internal HECTR index.

LOTRIP(ij) [I] Number of trip that triggers opening of this leak.

LCTRIP(ij) [I] Number of trip that triggers closing of this leak.

LATABO(ij) [I] Number of table that defines fraction open for the leak while opening.

LOPTYP(ij) [I] Type of x variable in opening table.
=1 time elapsed since trip became true
=2 differential pressure (compartment - atmosphere with gravity head adjustment).

LATABC(ij) [I] Number of table that defines fraction open for the leak while closing.

LCLTYP(ij) [I] Type of x variable in closing table.
=1 time elapsed since trip became true
=2 differential pressure (compartment - atmosphere with gravity head adjustment).

end if

if $-3 \leq$ NCF(i) ≤ -1 then
>>>
In the following, ij is an internal HECTR index.

NID2(ij) [I] Number of compartment in which pressure test for starting timer (for reclosing leak) is made.

TPT2(ij) [R] (pascals)
Pressure in compartment NID2 that will trigger timer to start.

```
    DURLKO(ij)   [R]    (seconds)
                        Time that leak will remain open
                        following trip.

    LKFLAG(ij)   [I]    Flag for reopening leak after timer
                        shuts it.
                        = 1        leak remains locked shut
                                   after timer expires
                        not = 1    not currently implemented

    while column 1 not = '$'
>>>
      TVCLO      [R]    (seconds)
                        Differential time entry for "A vs dt"
                        closing table.

      FVCLO      [R]    Fraction open entry for "A vs dt"
                        closing table (fraction open is
                        multiplied by AFL to get area for flow
                        rate calculation).
    end while
  end if
end for

for i=1,NOT
>>>
  A1(i)          [R] - (square meters)
                       Initial leakage area for temperature-
                       dependent leakage.

  A2(i)          [R] - (square meters)
                       Final leakage area for temperature-
                       dependent leakage.

  T1(i)          [R] - (seconds)
                       Temperature-dependent soak time.

  T2(i)          [R] - (seconds)
                       Temperature-dependent seal
                       decomposition time.

  TEST(i)        [R] - (kelvins)
                       Temperature-dependent threshold
                       temperature.
end for

for i=1,NOP
>>>
  NHY(i)         [I] - Hysteresis flag.  Enter
                          0      for no pressure-dependent
                                 hysteresis
                          1      to include pressure-dependent
                                 hysteresis.
```

```
  IND(i)          [I] - Hysteresis curve is normalized to the
                        INDth member of the pressure-dependent
                        curve.
>>>
  for j=1,10
     DPL(i,j)     [R] - (pascals)
                        Differential pressures for pressure-
                        dependent leakage tables.
  end for

>>>
  for j=1,10
     ALK(i,j)     [R] - (square meters)
                        Ascending leakage areas for pressure-
                        dependent leakage tables.
  end for

>>>
  for j=1,10
     FLK(i,j)     [R] - Conversion factors for hysteresis.
  end for
end for
```

3.2.2.6 Flow Junction Data

If this simulation does not include flow junctions, then enter a $ in column 1 and skip the rest of this section of input.

```
while column 1 not = '$'
>>>
  Enter data associated with the nth flow junction (assuming
  the direction of positive flow is from compartment i into
  compartment j).

  i               [I] - Source compartment.  If this number is
                        less than zero (-k), then the source
                        compartment will be assumed to be the
                        top compartment of the kth stack in the
                        ice-bed region of an ice condenser, and
                        the receiving compartment should be an
                        upper plenum.

  j               [I] - Receiving compartment.  If this number
                        is less than zero (-k), then the
                        receiving compartment will be assumed
                        to be the bottom compartment of the kth
                        stack in the ice-bed region of an ice
                        condenser, and the source compartment
                        should be a lower plenum.

  JTYPE(n)        [I] - Junction type.  Enter
```

1 for 2-way flow
2 for check valve type of 1-way flow
3 for inertial valve type of 1-way flow (variable area door)
4 for a drain between the upper and lower compartments in an ice-condenser containment
5 for a blowout panel junction
6 for a flood junction or flood junction with blowout panels.
7 for valves (fraction open controlled by trips and tables)

AI(n) [R] - (square meters)
Interconnection area. For valve-type flow junctions (JTYPE = 2 or 3), this is the fully open door area. For junctions with blowout panels (JTYPE = 5 or 6), this is the flow area after the panels blow out.

FLOCO(n) [R] - Loss coefficient for flow between compartments i and j.

LA(n) [R] - (1/meters)
The flow length through the junction divided by an effective flow area. See Section 3.4 of Reference 2 for further information.

RELATJ(n) [I] - Describes the spatial relationship of compartment i to compartment j for burn propagation. Enter
-1 if i is above j
0 if i is beside j
1 if i is below j

ZJUN(n) [R] - (meters)
Junction elevation. This elevation is referenced to the same baseline as the compartment elevations (see Z(i) in the Compartment Data section).

if JTYPE(n) = 3 then (junction allows inertial valve type of 1-way flow)

>>>

In the following, "ii" is the number of the inertial valve (door) corresponding to flow junction n. "ii" is an internal HECTR index.

DAMIN(ii) [R] - (square meters)
Minimum door area. The door has this area for differential pressures across the door that are less than DPMIN(ii).

```
    DPMIN(ii)    [R] - (pascals)
                       Minimum differential pressure needed to
                       begin opening the door.

    DPMAX(ii)    [R] - (pascals)
                       Differential pressure necessary to hold
                       the door fully open.

    THETMX(ii)   [R] - (radians)
                       Fully open door angle.  This number
                       must lie between 0 and  π/2, inclu-
                       sive.
  end if

  if JTYPE(n) = 4 then   (junction is a drain)
>>>
    In the following, "ij" is the number of the drain corre-
    sponding to flow junction n.  "ij" is an internal HECTR
    index.

    ISUMPD(ij)   [I] - Number of the lower-compartment sump
                       which the drain feeds into.

    VSMPDR(ij)   [R] - (cubic meters)
                       Volume of water in the above sump
                       (ISUMPD(ij)) needed to cover the drain
                       opening and block gas flow.
  end if

  if JTYPE(n) = 5 then  (blow out panel)
>>>
    In the following, ij is an internal HECTR index.

    DPOPEN(ij)   [R] - (pascals)
                       Differential pressure needed to blow
                       out panel.

  end if

  if JTYPE(n) = 6 then  (flood junction)
>>>
    In the following, ij is an internal HECTR index.

    VSMPMN(ij)   [R] - (cubic meters)
                       Sump volume at which junction flooding
                       begins.

    VSMPMX(ij)   [R] - (cubic meters)
                       Sump volume at which junction is
                       completely covered.

    ISMPNR       [I] - Number of sump that results in junction
                       flooding.
```

```
    IBLCHK(ij)  [I] - Blowout panel flag.  Enter
                          0      for no blow out panel
                          1      if this is a blow out panel.

    if IBLCHK(ij) = 1 then
>>>
       DPOP(ij) [R] - (pascals)
                      Differential pressure needed to blow
                      out panel.
    end if
  end if

  if JTYPE(n) = 7 then     (valve)

    In the following, "ij" is the number of the valve corre-
    sponding to flow junction n and is an internal HECTR
    index.
>>>
    JOTRIP(ij)  [I]   Trip number for opening valve (See
                      Section 3.2.3.7).

    JCTRIP(ij)  [I]   Trip number for closing valve.

    JBTRIP(ij)  [I]   Trip number for permanently blowing
                      open junction.

    ABLOWN(ij)  [R]   (square meters)
                      Area of junction after it blows open.

>>>
    JATABO(ij)  [I]   Table number to use when opening valve

    TOPTYP(ij)  [I]   Type of input in opening table.  Enter
                          1      for fraction open versus time
                          2      for fraction open versus
                                 differential pressure across
                                 junction.

    JATABC(ij)  [I]   Table number to use when closing valve.

    TCLTYP(ij)  [I]   Type of input in closing table.  Same
                      input options as for opening table (See
                      above).
  end if
end while
```

3.2.2.7 Ice-Condenser Data

\>>>
If this simulation does not include an ice condenser, then

enter a $ in column 1 and skip the rest of this section of input. This section of input deals primarily with the ice-bed region. The lower and upper plena should already have been entered as regular compartments.

```
NLPCOM              [I] - Number of compartments being used to
                          simulate the lower plenum.

NUPCOM              [I] - Number of compartments being used to
                          simulate the upper plenum.

>>>
for i=1,NUPCOM
  IUP               [I] - Compartment number corresponding to
                          upper plenum i.
end for

>>>
for i=1,NLPCOM
  ILP               [I] - Compartment number corresponding to
                          lower plenum i.

  ISICE             [I] - Number of the sump that will receive
                          the water that is produced from ice
                          melting and steam condensation in the
                          ice-condenser compartments and falls
                          into lower plenum compartment ILP.
end for

>>>
for i=1,NICEX       (Number of ice condenser columns.  See
                    Section 3.2.1.3)

  ICD(i)            [I] - Number of lower plenum compartment that
                          ice column i will drain into.
end for

>>>
MICET               [R] - (kilograms)
                          Total mass of the ice initially present
                          in the ice condenser.

AICET               [R] - (square meters)
                          Total heat-transfer area of the ice
                          initially present.  Normally, this is
                          the sum of the surface areas of the
                          full ice baskets, treating each as a
                          smooth right circular cylinder, i.e.,
                          do not attempt to differentiate between
                          the ice and the baskets.

TICE                [R] - (kelvins)
                          Initial temperature of the ice.
```

LICET [R] - (meters)
Total (vertical) length of the ice initially present.

EMISIC [R] - Radiative emissivity of the ice.

VICET [R] - (cubic meters)
Total volume of the ice initially present.

>>>
MSTRCT [R] - (kilograms)
Total mass of heat-transfer structures, excluding baskets, in the ice region.

ASTRCT [R] - (square meters)
Total heat-transfer area of the structures, excluding baskets, present in the ice region.

CSTRUC [R] - (joules per kilogram per kelvin)
Specific heat of the heat-transfer structures in the ice region.

EMISTR [R] - Radiative emissivity of the heat-transfer structures in the ice region.

>>>
MBASKT [R] - (kilograms)
Total metal mass of the ice baskets in the ice condenser.

ABASKT [R] - (square meters)
Total heat-transfer area of the ice baskets after all the ice has melted.

TMELTF [R] - (kelvins)
Final temperature of water, producedfrom melting ice and steam condensation on the ice, after it falls through the lower plenum.

>>>
ZBOT [R] - (meters)
Elevation of the bottom of the ice region in the ice condenser.

VOLICE [R] - (cubic meters)
Initial free gas volume in the ice region.

>>>
AFICE [R] - (square meters)
Cross-sectional area for upward flow

through the ice bed when ice baskets are full of ice.

AFIMX [R] - (square meters)
Cross-sectional area for upward flow through the ice bed when all ice has melted.

LOSCO [R] - Loss coefficient to be applied at all upward flow junctions when ice baskets are full of ice.

LOSMX [R] - Loss coefficient to be applied at upward flow junctions when all ice in the two connected compartments has melted.

>>>

AXICE [R] - (square meters)
Flow area for cross flow in ice bed when ice baskets are full of ice.

AXIMX [R] - (square meters)
Flow area for cross flow in ice bed when all ice has melted.

LOSCOX [R] - Loss coefficient to be applied at all cross-flow junctions when the ice in baskets are full of ice.

LOSXMX [R] - Loss coefficient to be applied at cross flow junctions when all ice in the two connected compartments has melted.

XLAICE [R] - (1/meters)
Inertial L/A factor for all cross flow junctions (See discussion of L/A in Section 3.2.2.6).

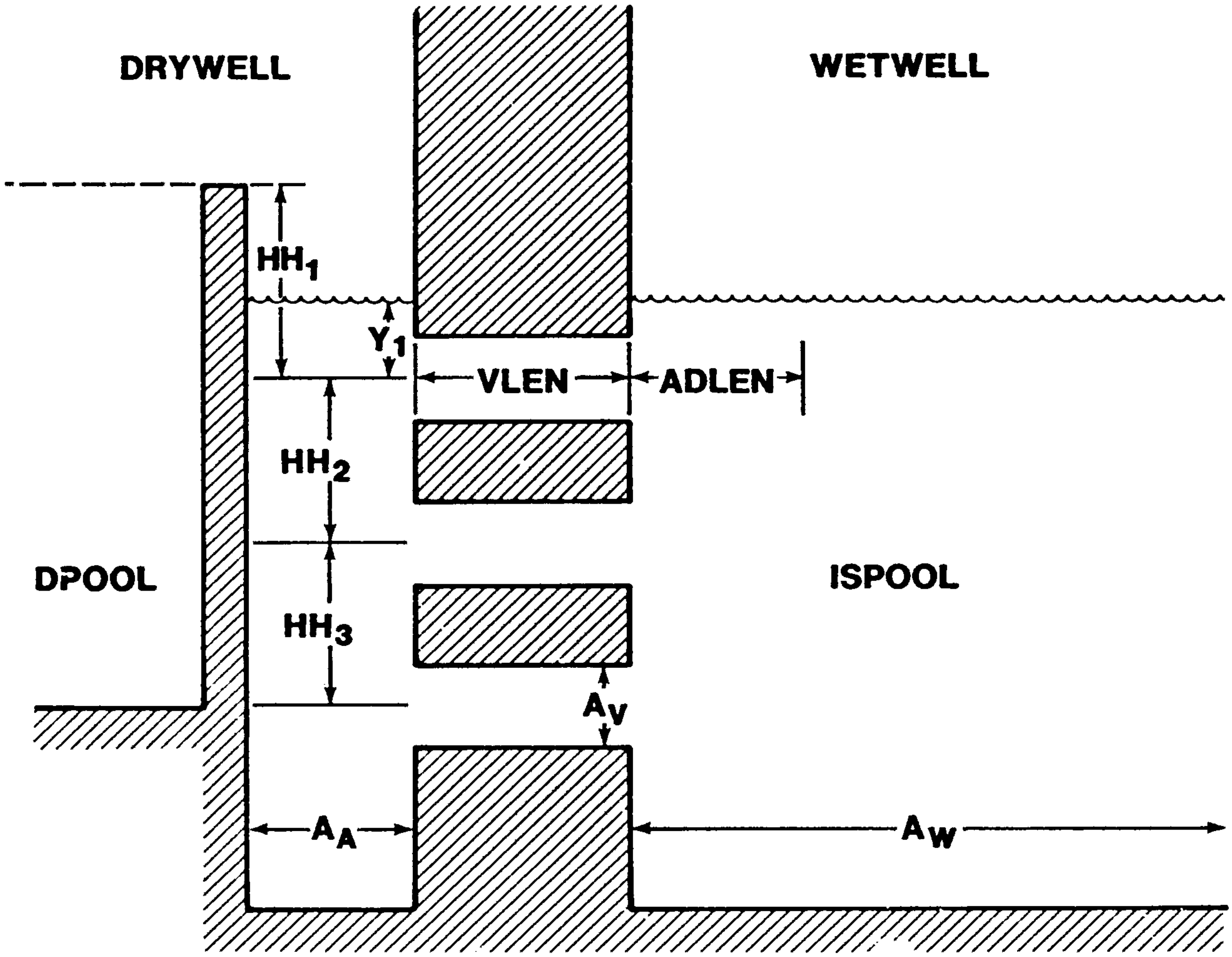
3.2.2.8 Suppression Pool Data

>>>

If this simulation does not include a suppression pool, then enter a $ in column 1 and skip the rest of this section of input. Figure 3.2 shows several of the suppression pool input variables. See Sections A.2.10 and 3.13 of Reference 2 for discussions of these variables.

ISPOOL [I] - Number of the sump that is the suppression pool.

UPOOL [I] - Number of the upper pool sump. (If an upper pool dump is not being simulated,



A_A = SURFACE AREA OF DRYWELL SIDE OF SUPPRESSION POOL
A_V = CROSS-SECTIONAL AREA OF 1 ROW OF VENTS
A_W = SURFACE AREA OF WETWELL SIDE OF SUPPRESSION POOL

Figure 3.2. Suppression Pool Input Variables

this value may be set to 0, and dummy values input below for WDRNUP, TDRNUP, and MMINUP).

DPOOL [I] - Number of the drywell sump.

while column 1 not = '$'

>>>
Enter data for each of the drywell compartments

DW(i) [I] - Drywell compartment number.

DWWT(i) [R] - Weighting factor for averaging pressure and distributing vent flow (See section A.2.10 of Reference 2).

end while

while column 1 not = '$'

>>>
Enter data for each of the wetwell compartments

WW(i) [I] - Wetwell compartment number.

WWWT(i) [R] - Weighting factor for averaging pressure and distributing vent flow (See section A.2.10 of Reference 2).

end while

>>>
HH(1) [R] - (meters)
Distance from the top of the weir wall to the center of the top vent.

HH(2) [R] - (meters)
Distance between the centers of the top and middle vents.

HH(3) [R] - (meters)
Distance between the centers of the middle and bottom vents.

VLEN [R] - (meters)
Vent length. This is the thickness of the drywell wall (wall between the drywell and wetwell).

Y(1) [R] - (meters)
Initial distance from the surface of the suppression pool to the center of the top vent. The drywell and wetwell sides are assumed to be at the same level initially (Y(7) = Y(1)).

ZSPBOT [R] - (meters)
Elevation of the centerline of the bottom vent.

>>>
AA [R] - (square meters)
Area of the drywell portion of the suppression pool surface.

AV [R] - (square meters)
Total cross-sectional area of one horizontal row of suppression pool vents.

AW [R] - (square meters)
Area of the wetwell portion of the suppression pool surface.

KIN [R] - Loss coefficient on the drywell side for water flowing through the vent opening (same value used for flow in either direction).

KOUT [R] - Loss coefficient on the wetwell side for water flowing through the vent opening (same value used for flow in either direction).

KVENT [R] - Loss coefficient for gas flowing through one horizontal row of vents.

ADLEN [R] - (meters)
Equivalent additional vent length used in vent clearing calculations.

>>>
WDRNUP [R] - (kilograms per second)
Draining rate of the upper pool into the suppression pool for upper pool dump.

TDRNUP [R] - (seconds)
Absolute time when the upper pool begins to drain into the suppression pool (see also the discussion of TIMZER in Section 3.2.3.10.4).

MMINUP [R] - (kilograms)
Residual mass of water left in the upper pool after upper pool dump has occurred.

3.2.2.9 Fan Data

>>>
If this simulation does not include fans, then enter a $ in column 1 and skip the rest of this section of input.

TSETF [R] - (kelvins)
Temperature set point for automatic activation of the fans. This quantity is used when the fans are in AUTO mode (described later), otherwise this value is ignored.

PSETF [R] - (pascals)
Pressure set point for automatic activation of the fans. This quantity is used when the fans are in AUTO mode (described later), otherwise this value is ignored.

DELAYF [R] - (seconds)
Time delay for fan activation in AUTO mode. The fans are turned on at a time DELAYF after either TSETF or PSETF is exceeded anywhere in the containment (excluding the drywell if a suppression pool is modeled).

TFRUN [R] - (seconds)
Length of time that the fans will remain on once they have been turned on. If the fans should continue to operate indefinitely, then enter a large number. This time applies to all modes of fan operation (see FANS in Section 3.2.3.10.4).

while column 1 not = '$'

>>>
Enter data associated with the nth fan path (assuming the direction of flow is from compartment i into compartment j).

i [I] - Source compartment.

j [I] - Receiving compartment.

FANVFR(n) [R] - (cubic meters per second)
Volumetric flow rate of the fan. Enter

+X if the fan is blowing at a constant flow rate of X or
-X if the fan is blowing at a maximum flow rate of X, with the actual flow rate determined from a head curve.

DPFMAX(n) [R] - (pascals)

Maximum pressure difference under which the fan can operate when using a head curve (shut-off head).

ETA(n) [R] - Fan efficiency. This number is equal to 1. for an ideal fan.

RELATF(n) [I] - Describes the spatial relationship of compartment i to compartment j for burn propagation through the fans. Enter

-1 if i is above j
0 if i is beside j
1 if i is below j

end while

Enter a head curve for the fans. This curve will be used for all fans that are using a head curve to determine their volumetric flow rate. If the default head curve is desired, enter a $ in column 1 and skip the rest of this section of input.

while column 1 not = '$'

>>>
Enter the head curve table. "if" is an internal HECTR index that starts counting from 1. The maximum number of table entries is 11.

PHEAD(if) [R] - Normalized value of the differential pressure across the fan (P(j)-P(i))/DPFMAX).

FRHEAD(if) [R] - Normalized value of the fan volumetric flow rate (flow rate/FANVFR).

end while

3.2.2.10 Fan Cooler Data

>>>
If this simulation does not include a fan cooler, then enter a $ in column 1 and skip the rest of this section of input.

PSETFC [R] - (pascals)
Pressure set point for switching into LOCA mode of fan cooler operation.

DELAFC [R] - (seconds)
Time delay for switching to LOCA mode after pressure in any compartment exceeds PSETFC.

TFCRUN [R] - (seconds)
Length of time that the fan cooler will run after being turned on and length of time fan cooler will run after switching into LOCA mode.

>>>
See Figure 3-3 for an illustration of the variables used to define the fan cooler geometry.

NCROWS [I] - Number of rows of coils in a coil unit.

NCIRC [I] - Number of circuits in a coil unit.

VP [R] - (meters)
Vertical pitch of coils.

HP [R] - (meters)
Horizontal pitch of coils.

COD [R] - (meters)
Coil outer diameter.

CID [R] - (meters)
Coil inner diameter.

COILL [R] - (meters)
Coil length.

HFG [R] - (kelvins times square meters per watt)
Heat transfer fouling factor for gas flow side of coils.

HFW [R] - (kelvins times square meters per watt)
Heat transfer fouling factor for coolant side of coils.

CONDCM [R] -(watts per meter per degree kelvin)
Thermal conductivity of coils.

XK [R] - (watts per meter per degree kelvin)
Thermal conductivity of fins.

DELT [R] -(meters)
Thickness of fins.

ITBEL [I] - Indicates relative location of fan and coils. Enter
0 for fan upstream of coils
1 for fan downstream of coils.

while column 1 not = '$'

>>>

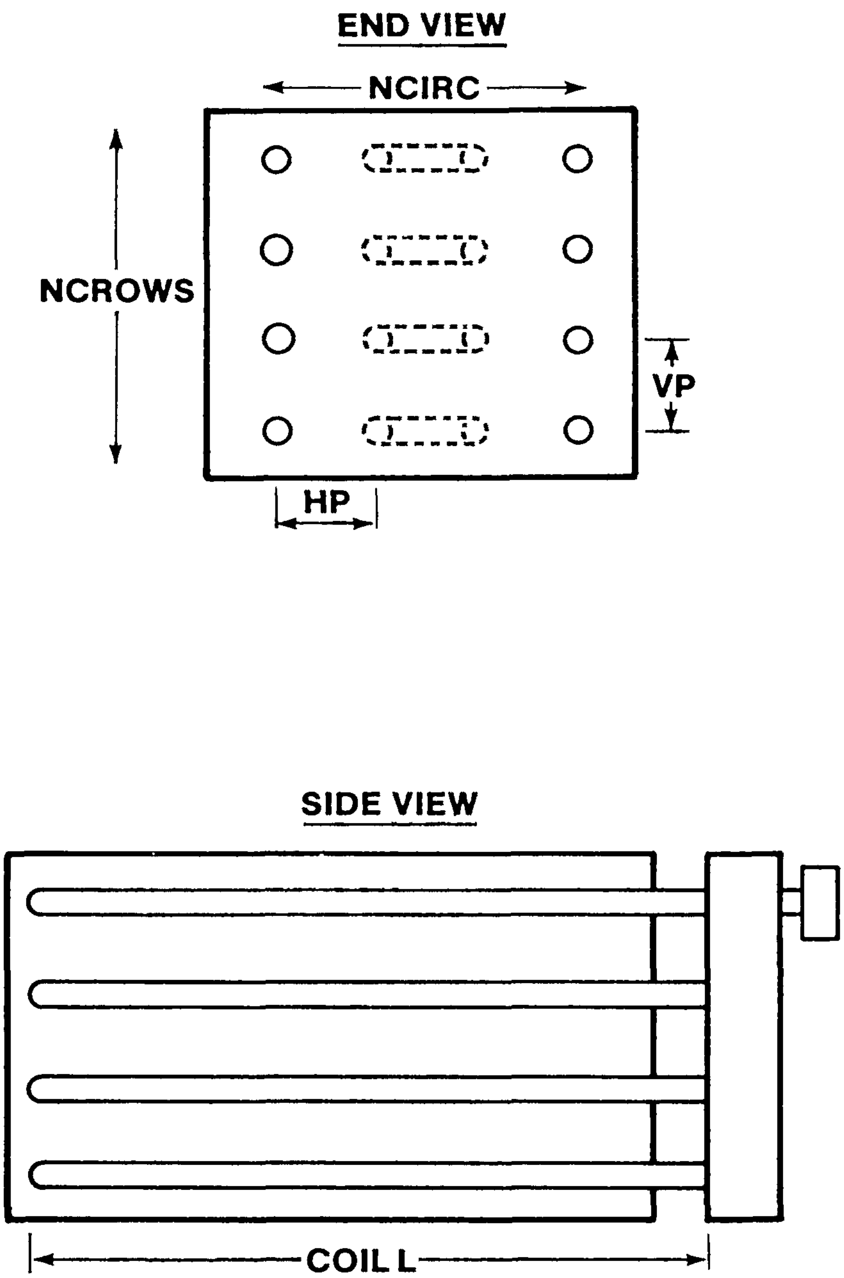


Figure 3.3. **Fan Cooler Input Variables**

Enter data for fan cooler assemblies that operate both in normal mode and LOCA mode (Assemblies that only operate in LOCA mode are input in the following section). "ij" refers to an internal HECTR index.

FRMFC(ij) [I] - Compartment that assembly draws from

QDTRN(ij) [R] - (watts)
Rated capacity in normal mode.

QDTRL(ij) [R] - (watts)
Rated capacity in LOCA mode.

QFANN(ij) [R] - (cubic meters per second)
Rated fan flow rate in normal mode.

QFQNL(ij) [R] - (cubic meters per second)
Rated fan flow rate in LOCA mode.

NFCU(ij) [I] - Total number of coil units in this assembly.

end while

while column 1 not = '$'

>>>
Enter data for fan cooler assemblies that only operate in LOCA mode. "ij" refers to an internal HECTR index.

FRMFC(ij) [I] - Compartment that assembly draws from

QDTRL(ij) [R] - (watts)
Rated capacity in LOCA mode.

QFQNL(ij) [R] - (cubic meters per second)
Rated fan flow rate in LOCA mode.

NFCU(ij) [I] - Total number of coil units in this assembly.

end while

>>>
CVFRN [R] - (cubic meters per second)
Coolant volumetric flow rate per coil unit in normal mode (Same flow rate used in all coil units in all assemblies).

TCIN [R] - (kelvins)
Coolant inlet temperature for normal mode (Same inlet temperature used for all coil units in all assemblies).

CVFRL [R] - (cubic meters per second)
Coolant volumetric flow rate per coil unit in LOCA mode (Same flow rate used in all coil units in all assemblies).

TCIL [R] - (kelvins)
Coolant inlet temperature for LOCA mode (Same inlet temperature used for all coil units in all assemblies).

FCSRC [I] - Number of sump that condensate will drain into.

while column not = '$'

>>>
Enter data for each path in the fan cooler outlet ducting that is open during both normal and LOCA modes (Data for paths that are only open during LOCA mode is input in the following section). "ij" refers to an internal HECTR index.

TOFC(ij) [I] - Compartment that this path normally exits into (prior to flooding).

FCFRAC(ij,1) [R] - Fraction of the total fan cooler flow that is exhausted through this path while in the normal mode.

FCFRAC(ij,2) [R] - Fraction of the total fan cooler flow that is exhausted through this path while in the LOCA mode.

TOFF(ij) [I] - Compartment that this path will exhaust into if the normal outlet path is flooded.

VSFD(ij) [R] - (cubic meters)
Volume of sump that causes the normal path exit to be flooded.

JSMPNR(ij) [I] - Number of sump that has the potential for flooding this fan cooler outlet path.

end while

while column not = '$'

>>>
Enter data for each path in the fan cooler outlet ducting that is only open during LOCA mode. "ij" refers to an internal HECTR index.

TOFC(ij) [I] - Compartment that this path normally exits into (prior to flooding).

```
  FCFRAC(ij,2)    [R] - Fraction of the total fan cooler flow
                        that is exhausted through this path
                        while in the LOCA mode.

  TOFF(ij)        [I] - Compartment that this path will exhaust
                        into if the normal outlet path is
                        flooded.

  VSFD(ij)        [R] - (cubic meters)
                        Volume of sump that causes the normal
                        path exit to be flooded.

  JSMPNR(ij)      [I] - Number of sump that has the potential
                        for flooding this fan cooler outlet
                        path.

end while
```

3.2.2.11 Radiative Heat-Transfer Data

if RAD = FALSE following initial NAMELIST call, skip this section of input (See discussion in introduction to Section 3.2.1).

```
for i=1,"Number of Surfaces"     (see Section 3.1.3)

>>>
  for j=i,"Number of Surfaces"

     BEAM(i,j)    [R] - (meters)
                        Beam length between surfaces i and j.
                        BEAM(j,i) is automatically set equal to
                        BEAM(i,j) so that only half of the
                        array must be specified.
  end for

end for

for i=1,"Number of Surfaces"     (see Section 3.1.3)

>>>
  for j=i,"Number of Surfaces"

     VF(i,j)      [R] - View (shape) factor for surface i
                        looking at surface j.  VF(j,i) is cal-
                        culated automatically using the reci-
                        procity relation for view factors
                        ( AREA(I)*VF(I,J) = AREA(J)*VF(J,I) ).
                        See Section 3.7 for further informa-
                        tion.

  end for

end for
```

3.2.2.12 Spray Data

```
>>>
INSPTR            [I]    Number of independently actuated spray
                         trains.  Note that each train can
                         inject into multiple compartments.  If
                         this number is zero, then skip the rest
                         of this section of input.

for it=1,INSPTR

>>>
  INCWSP(it)      [I] -  Number of compartments with spray
                         sources.  This should include only
                         compartments in which spray is ini-
                         tially injected, not compartments that
                         are receiving spray carryover from
                         compartments above them.

  for i=1,INCWSP(it)

>>>
     INITSC(it,i)[I] -   Compartment that sprays are injected
                         into.  Only one spray source should be
                         specified for a compartment.

     TD0(it,i)    [R] -  (kelvins)
                         Spray inlet temperature when in
                         injection mode.  This value must be
                         less than 477 K.

     SPFLO(it,i) [R] -   (cubic meters per second)
                         Spray inlet flow rate.

     INDS(it,i)   [I] -  Number of drop sizes to be modeled in
                         the spray.

     for j=1,INDS(it,i)

>>>
       FREQ(it,i,j)    [R] -     Fraction of drops that are of
                                 the jth drop size (based on
                                 total number of drops rather
                                 than mass or volume).

       DIAM(it,i,j)    [R] -     (micrometers)
                                 Diameter of drops of the jth
                                 drop size.

     end for

  end for

  while column 1 not = '$'
```

```
>>>
    Enter data associated with spray carryover.  Note that
    information needs to be entered only for paths for which
    there is actually spray carryover.  If no spray carryover
    is allowed, then enter a $ in column 1 and skip to the
    end of this table input section.

    i             [I] - Source compartment for spray carryover.

    j             [I] - Compartment receiving spray carryover.

    FRDRP(it,i,j)      [R] -     Fraction of the drops that
                                 reach the bottom of
                                 compartment i that are
                                 allowed to carry over into
                                 compartment j.

  end while

  while column 1 not = '$'

>>>
    Enter spray fall heights.  Note that these values need to
    be entered only for compartments through which spray
    drops can actually fall (i.e., spray injection and
    carryover compartments).

    i             [I] - Compartment.

    ZTOT(it,i)    [R] - (meters)
                        Spray fall height for compartment i.

  end while

>>>
    Enter spray actuation criteria.

  NCRI(it)        [I] - Number of top level criteria in "or"
                        configuration.

  for i=1,NCRI(it)

>>>

    N2CRI(it,i) [I] - Number of second level criteria in
                      "and" configuration.

    for m=1,N2CRI(it,i)

>>>
       NCRCOM(it,i,m)  [I] -     Number of compartments to be
                                 tested for second level
                                 criterion m.
```

for j=1,NCRCOM(it,i,m)

\>>>

NSPCOM(it,i,m,j) [I] Compartment number for test j.

PSET(it,i,m,j) [R] (Pascals)
Pressure that must be exceeded in compartment NSPCOM(it,i,m,j) that, in conjunction with TSET below causes the jth test to be true.

\>>>

TSET(it,i,m,j) [R] (kelvins)
Temperature that must be exceeded in compartment NSPCOM(it,i,m,j) that, in conjunction with PSET above, causes the jth test to be true.

end for

\>>>

NCOMX(it,i,m) [I] - Number of compartments that must meet the PSET and TSET criteria for second level criteria m to be true. This number should be less than or equal to NCRCOM(it,i,m).

end for

end for

\>>>

DELAY(it) [R] - (seconds)
Time delay for spray activation in AUTO mode. The sprays are turned on at a time DELAY after a top-level criteria is met for spray train it (excluding the drywell compartments if a suppression pool is modeled).

TSPRUN(it) [R] - (seconds)
Length of time that the sprays will remain on once they have been turned on. If the sprays should continue to operate indefinitely, then enter a large number. This time applies to all modes of spray operation (see SPRAYS in Section 3.2.3.10.4).

end for

>>>
Enter data associated with sprays in recirculation mode. If this data is not relevant to the simulation, then enter a $ in column 1 and skip the rest of this section of input. Note that <u>all</u> sprays will be switched to the recirculation mode when TINJ has been exceeded. Also, all spray water will come from a single sump and pass through a single heat exchanger. Thus, if sprays are injected into more than one compartment, the total flow necessary to supply the sprays will be drawn from a single sump and passed through a single heat exchanger with splits occurring downstream of the spray heat exchanger. Therefore, the spray heat exchanger parameters should be based on <u>total</u> spray flow rates. Currently, the sprays will switch to recirculation based on the last train to actuate, i.e., TINJ is reset each time a spray train meets its criteria. Thus, some problems may arise when dealing with multiple trains, and the user should exercise caution when using multiple trains in recirculation mode.

TINJ	[R] - (seconds) Time that the sprays spend in injection mode before switchover to the recirculation mode.
SPFLOR	[R] - (kilograms per second) Rated spray heat exchanger mass-flow rate.
HAEFFR	[R] - (watts per kelvin) Rated spray heat exchanger effective heat-removal rate.
TS1	[R] - (kelvins) Spray heat exchanger secondary side inlet temperature.
WSR	[R] - (kilograms per second) Spray heat exchanger secondary side mass-flow rate.
SPRSRC	[I] - Number of the sump from which the sprays draw water when in recirculation mode. This is also the sump from which water is drawn for recirculation into the emergency core cooling system(see Section 3.4.2) when using an external (MARCH) source.

3.2.2.13 Sump Heat Exchanger Data

If this simulation does not include sump heat exchangers, then enter a $ in column 1 and skip the rest of this section of input. Unlike the spray heat exchanger, multiple heat exchangers can be specified for sump cooling. When modeling plants where heat exchangers are shared between the sprays and sump cooling, it is necessary to provide input for two heat exchangers. The input for sump cooling is provided in this section, and the input for spray cooling is provided in the Spray Data input section.

while column 1 not = '$' then

```
>>>
  i                [I] - The number of the sump to be cooled by
                         a heat exchanger.

  MODEHE           [I] - Enter

                              1   if the heat exchanger is turned
                                  off when the sprays come on
                              0   if the heat exchanger is not
                                  affected by sprays

  FLOHER(i)        [R] - (kilograms per second)
                         Rated mass flow rate.

  EFFHE(i)         [R] - (watts per kelvins)
                         Rated effective heat removal rate.

  TSECHE(i)        [R] - (kelvins)
                         Secondary side inlet temperature.

  WSECHE(i)        [R] - (kilograms per second)
                         Secondary side mass flow rate.

  FLOWHE(i)        [R] - (kilograms per second)
                         Actual primary side mass flow rate that
                         passes through the heat exchanger.

>>>
  TSETH(i)         [R] - (kelvins)
                         Temperature set point for automatic
                         activation of the heat exchanger.  This
                         quantity is used when the heat
                         exchanger is in AUTO mode (described
                         later), otherwise this value is
                         ignored.

  PSETH(i)         [R] - (pascals)
                         Pressure set point for automatic acti-
                         vation of the heat exchanger.  This
```

quantity is used when the heat exchanger is in AUTO mode (described later), otherwise this value is ignored.

DELAYH(i) [R] - (seconds)
Time delay for heat exchanger activation in AUTO mode. The heat exchanger is turned on at a time DELAYH(i) after either TSETH(i) or PSETH(i) is exceeded anywhere in the containment, excluding the drywell if a suppression pool is modeled.

THERUN(i) [R] - (seconds)
Length of time that the heat exchanger will remain on once it has been turned on. This time applies to all modes of heat exchanger operation (see HTEXCH(i) in Section 3.2.3.10.4).

end while

3.2.3 Initial Conditions and Accident Scenario

This data is read from unit UIC (UIC is defined in Section 3.2.1).

3.2.3.1 General

>>>
TRUN [R] - (seconds)
Simulation time.

3.2.3.2 Compartment Data

for i=1,"Number of Compartments" (see Section 3.1.3)

>>>
TBULK(i) [R] - (kelvins)
Initial gas temperature in compartment i.

for j=1,"Number of Gases (= 4 if COCO2 is FALSE, = 6 if COCO2 is TRUE)"

PP(i,j) [R] - (pascals)
Initial partial pressure of gas species j in compartment i where j equal to

1 indicates steam (H_2O)
2 indicates nitrogen (N_2)
3 indicates oxygen (O_2)
4 indicates hydrogen (H_2)

```
                                  5   indicates carbon monoxide (CO)
                                  6   indicates carbon dioxide  (CO2)

  end for

  UX(i)            [R] - (meters per second)
                         Convective gas velocity for forced
                         convection in compartment i.  During a
                         "discrete" burn, HECTR uses the flame
                         speed as the convective gas velocity
                         instead of this value.  See Section 3.8
                         for further information.

end for

if this simulation includes an ice condenser then

>>>
  TBICE            [R] - (kelvins)
                         Initial gas temperature in the ice
                         region of the ice condenser.

  for j=1,"Number of Gases (= 4 if COCO2 is FALSE, = 6 if
  COCO2 is TRUE)"

     PPICE(j)      [R] - (pascals)
                         Initial partial pressure of gas spe-
                         cies j (see PP(i,j) above for the
                         definition of the gas species) in the
                         ice region of the ice condenser.
  end for

end if

if NOL > 0 then   (skip this section if there are no
                   containment leaks).

>>>
  TATM             [R] - (kelvins)
                         Atmosphere temperature.

  for j=1,"Number of Gases (= 4 if COCO2 is FALSE, = 6 if
  COCO2 is TRUE)"

     PPATM(j)      [R] - (pascals)
                         Partial pressure of gas species j in
                         the atmosphere at elevation 0 (same
                         reference as compartment and junction
                         elevations).

  end for

end if
```

3.2.3.3 Source Data

Enter the source terms. Sources can be injected into either compartments or sumps. For each gas, if there are no sources, then enter a $ in column 1; otherwise read the location i in which there is a source, MODE, TORH and SSRCC (these variables are defined below). Next, the source term is specified in tabular fashion. The form of this input is TIME, the release RATE at this TIME and, if MODE was positive, the source temperature or enthalpy at this TIME. The actual source values used in HECTR at times intermediate to those specified are obtained from linear interpolation of the data. For times greater than the last TIME specified in the table, the source values at this last TIME will be used. Terminate the source table with a $ in column 1. Additional sources of this gas can then be specified in other locations in the same manner. Do not enter more than one source of the same gas in the same compartment. Terminate the current source gas input (which may include several tables) with a $ in column 1 (so that the last entry in the last table is followed by two dollar signs). Proceed then to the next source gas.

for j=1,"Number of Gases (= 4 if COCO2 is FALSE, = 6 if COCO2 is TRUE)"

while column 1 not = '$'

\>>>

i [I] - Location in which there is a source of gas species j where j equal to

1	indicates water (liquid or vapor)	(H_2O)
2	indicates nitrogen	(N_2)
3	indicates oxygen	(O_2)
4	indicates hydrogen	(H_2)
5	indicates carbon monoxide	(CO)
6	indicates carbon dioxide	(CO_2)

If i is positive, then the source is injected into compartment i. If i is negative then the source is injected into the sump numbered -i.

MODE [I] - Indicates whether the source temperature or enthalpy will be specified. For the <u>absolute value</u> of MODE equal to

1 source temperature (kelvins) is specified

2 source enthalpy (joules per kilogram) using Janaf table base point is specified

3 source enthalpy (joules per kilogram) using steam table base point (i.e., the enthalpy is zero at 273.15 K) is specified.

If MODE is negative, then TORH will specify the constant temperature or enthalpy of the source. Otherwise, for positive MODE, TORH will be ignored (but must still be entered), and the source temperature or enthalpy will be read in as a function of time along with the release rates.

TORH [R] - (kelvins OR joules per kilogram) Constant temperature or enthalpy of the source. This has meaning only if MODE (see above) is negative, but a value must always be entered.

SSRCC [I] - For sources injected into sumps, compartment that source will flow into after being cooled to sump temperature. Enter 0 to divide source using heat transfer surface area ratios (see section A.2.9) or if this source is not being injected into a sump.

while column 1 not = '$'

\>>>

TIME [R] - (seconds) The absolute time at which the release rate (specified next) occurs (see also the discussion of TIMZER in Miscellaneous Variables below).

RATE [R] - (kilograms per second) Release rate of the source into location i at the given TIME.

if MODE > 0 then

TORH [R] - (kelvins OR joules per kilogram) Source temperature or enthalpy at the given TIME (see mode above).

end if

end while

end while

end for

3.2.3.4 Sump Water Removal Rates

Enter tables of sump water removal rates. These tables can be used to simulate emergency core cooling (ECC) recirculation. If there are no such tables, then enter a $ in column 1 and skip the rest of this section of input. Otherwise, read the number of the sump (isump) for which a leakage table will be specified. Next, enter the table. The form of this input is the time (TLEAKE) and the leakage rate at this time (WLEAKE). The actual leakage values used in HECTR at times intermediate to those specified are obtained from linear interpolation of the data. For times greater than the last time specified in the table, the leakage values at this last time will be used. Terminate the leakage table with a $ in column 1. Additional leakage tables can now be specified for other sumps in the same manner. Terminate this section of input (which may include several tables) with a $ in column 1 (so that the last entry in the last table is followed by two dollar signs).

```
while column 1 not = '$'

>>>
  isump           [I] - The number of the sump from which water
                        is to be removed during the run.

  while column 1 not = '$'

>>>
     TLEAKE       [R] - (seconds)
                        The absolute time at which the leakage
                        rate (specified next) occurs (see also
                        the the discussion of TIMZER in Section
                        3.2.3.10.4).

     WLEAKE       [R] - (kilograms per second)
                        Leakage rate of water from sump isump
                        at the given time (TLEAKE).

  end while

end while
```

3.2.3.5 Compartment Energy Sources

Enter tables of compartment energy addition rates. If there are no such tables then enter a $ in column 1 and skip the rest of this section of input. Otherwise, read the compartment number (IDHT) for which an energy addition table will be specified. Next, enter the table. The form of this input is the time (TDHTE) and the energy addition rate at this time (EDHTE). The actual energy addition rates used in HECTR at times intermediate to those specified are obtained from linear interpolation of the data. For times greater than the last time specified in the table, the energy addition rates at this last time will be used. Terminate the energy addition table with a $ in column 1. Additional energy addition tables can now be specified for other compartments in the same manner. Terminate this section of input (which may include several tables) with a $ in column 1 (so that the last entry in the last table is followed by two dollar signs).

while column 1 not = '$'

```
>>>
  NESCMP          [I] - The number of the compartment to which
                        energy is being added.

  while column 1 not = '$'

>>>
     TDHTE        [R] - (seconds)
                        The absolute time at which the energy
                        addition rate (specified next) occurs
                        (see also the discussion of TIMZER in
                        Section 3.2.3.10.4).

     EDHTE        [R] - (watts)
                        Energy addition rate to compartment
                        IDHT at the given time (TDHTE).
  end while

end while
```

3.2.3.6 Continuous Burning Compartments

If this simulation does not include continuous burning compartments, then enter a $ in column 1 and skip the rest of this section of input. In this section, combustible gas refers to hydrogen plus 0.591 times carbon monoxide (masses or mole fractions, depending on variable). Diluent refers to steam plus carbon dioxide. (This is consistent with the treatment of discrete burns. See Table A-2 in Reference 2.) "ij" refers to an internal HECTR index.

while comumn 1 not = '$'

```
>>>
  CBCOMP(ij)      [I] - Number of compartment that is to be
                        modeled as a continuous burning
                        compartment.

>>>
  H2MINS(ij)      [R] - (kilograms per second)
                        Minimum combustible gas inflow rate for
                        this compartment (sources, junctions,
                        fans, etc.) for continuous burning.
```

STMH2R(ij) [R] - Maximum ratio of total diluent mass inflow to total combustible gas mass inflow for this compartment for continuous burning.

XOMNCB(ij) [R] - Minimum oxygen mole fraction in this compartment needed to support continuous burning.

XSMXCB(ij) [R] - Maximum diluent concentration (steam plus carbon monoxide mole fraction) in this compartment beyond which continuous burning will cease.

CBT(ij) [R] - (kelvins)
Spontaneous recombination temperature. If the compartment temperature exceeds this value, continuous burning will be allowed regardless of the values of the previously entered limits (e.g., STMH2R).

FRHCB(ij) [R] - Fraction of the total inflowing combustible gas that will be burned if continuous burning is occurring.

end while

3.2.3.7 Trips

If this simulation does not include any trips, then enter a $ in column 1 and skip the rest of this section of input.

while column 1 not = '$'

>>>
Enter data associated with the nth trip.

IDTRIP(n) [I] User-specified trip number (may be different than n)

TRPTYP(n) [I] Type of trip. For all of the options, input a positive value to perform a "greater than" test or a negative value to perform a "less than" test. Input

- 1 for compartment pressure
- 2 for differential pressure across junction
- 3 for compartment temperature
- 4 for time
- 5 for combination of other trips
- 6 for time since desired trip became TRUE

```
  ITRLCK(n)        [I]   Flag for locking trip open.  Input
                            1      to lock trip TRUE if it
                                   becomes TRUE
                            2      to allow trip to be reset to
                                   FALSE if the conditions are
                                   no longer satisfied

  NSATTR(n)        [I]   Number of tests in this trip that must
                         be satisfied for it to be TRUE

  while column 1 not = $

>>>
     TRPARG        [I]   Argument for trip test (compartment
                         number, junction number, trip number,
                         or input 0 if a time trip was
                         specified)

     TRPSET        [I]   Set point for trip

  end while

end while
```

3.2.3.8 Tables

If this simulation does not include any tables, then enter a $ in column 1 and skip the rest of this section of input.

```
while column 1 not = '$'

>>>
  Enter data associated with the nth table.

  IDTAB(n)         [I]   User-specified number identifying table
                         (can be different than n).

  while column 1 not = '$'

>>>
     TXVAL         [R]   Value of independent variable

     TYVAL         [R]   Value of dependent variable

  end while

end while
```

3.2.3.9 Surface Temperatures

```
>>>
for i=1,"Number of Surfaces"     (see Section 3.1.3)
```

TW(i) [R] - (kelvins)
Initial temperature of the ith surface. For slab surfaces all nodes will be set to this temperature.

end for

3.2.3.10 NAMELIST Input

This information is provided only when default values are to be overridden. The quantities within angle brackets indicate the default values for the variable. An (i) following the variable name indicates that this variable is an array.

>>>
3.2.3.10.1 Burn Model Parameters

BURNT(i) [R] - (seconds) <Defaults to an internal calculation>
Burn time for a discrete burn occurring in compartment i. If this quantity is not specified, then the burn time will be calculated by dividing the compartment characteristic length by the flame speed.

FLAMEV(i) [R] - (meters per second) <Defaults to an internal calculation>
Flame speed for a discrete burn occurring in compartment i. If this quantity is not specified, then an internal correlation based on the gas composition present at the start of the burn will be used. Do not enter both BURNT and FLAMEV for the same compartment.

FNLFH2(i) [R] - <Defaults to an internal calculation>
Final fraction of the initial concentration of hydrogen to be left at the end of a discrete burn in compartment i. This quantity is 1 minus the combustion completeness (specified as a fraction). For example, enter 0 or a small number for complete combustion. If this quantity is not specified, then an internal correlation based on the gas composition present at the start of the burn will be used.

FNLFCO(i) [R] - <Defaults to an internal calculation>
Final fraction of the initial concentration of carbon monoxide to be left

at the end of a discrete burn in compartment i. (See discussion of FNLFH2 above).

FDAMPR(i) [L] - <Default = TRUE>
If TRUE, then fan path i is assumed to have a nonreturn damper (or check valve) in it. This will prevent a discrete burn from propagating upstream through the fan under any circumstances or downstream through the fan when the fan volumetric flow rate is zero. If FALSE, then propagation downstream through a fan can occur for any flow rate, and propagation upstream can occur if the flow rate is zero or if the flow rate is nonzero and PRBKFN is TRUE.

KPROPF(i) [R] - <Default = .5>
Fraction of the burn time in either compartment connected by fan path i that must elapse before a discrete burn can propagate into the other compartment through the fan path. This number must lie between 0 and 1 inclusive.

KPROPJ(i) [R] - <Default = .5>
Fraction of the burn time in either compartment connected by flow junction i that must elapse before a discrete burn can propagate into the other compartment through the flow junction. This number must lie between 0 and 1 inclusive.

PRBKFN(i) [L] - <Default = FALSE>
If TRUE, then a discrete burn can propagate upstream through fan path i when the flow rate is nonzero and FDAMPR is FALSE. For zero flow rates, propagation through a fan is controlled by FDAMPR.

PRJUCL(i) [L] - <Default = FALSE if JTYPE(i) = 2 and
TRUE if JTYPE(i) = 3
If TRUE, then a discrete burn can propagate through flow junction i even if it is closed. Thus, by default, a burn will not propagate through a 1-way check valve (JTYPE(i) = 2) if it is closed, but a burn will propagate through a 1-way inertial valve

(JTYPE(i) = 3) even if the door area has been reduced to zero. This flag applies only to these two types of flow junctions. For ice-condenser drains (JTYPE(i) = 4) that are closed, burns cannot propagate through the drains under any circumstances.

XHMNIG(i) [R] - <Default = .07>
Minimum combustible gas (see Table A-2 in Reference 2) mole fraction needed for ignition in compartment i.

XHMNPD(i) [R] - <Default = .09>
Minimum combustible gas (see Table A-2 in Reference 2) mole fraction needed for downward propagation into compartment i.

XHMNPS(i) [R] - <Default = .06>
Minimum combustible gas (see Table A-2 in Reference 2) mole fraction needed for horizontal propagation into compartment i.

XHMNPU(i) [R] - <Default = .041>
Minimum combustible gas (see Table A-2 in Reference 2) mole fraction needed for upward propagation into compartment i.

XOMNIG(i) [R] - <Default = .05>
Minimum oxygen mole fraction needed for ignition in compartment i.

XOMNPD(i) [R] - <Default = .05>
Minimum oxygen mole fraction needed for downward propagation into compartment i.

XOMNPS(i) [R] - <Default = .05>
Minimum oxygen mole fraction needed for horizontal propagation into compartment i.

XOMNPU(i) [R] - <Default = .05>
Minimum oxygen mole fraction needed for upward propagation into compartment i.

XSMXIG(i) [R] - <Default = .55>
Maximum diluent (See Table A-2 in Reference 2) mole fraction that will permit ignition in compartment i.

XSMXPD(i) [R] - <Default = .55>
Maximum diluent (See Table A-2 in Reference 2) mole fraction that will permit downward propagation into compartment i.

XSMXPS(i) [R] - <Default = .55>
Maximum diluent (See Table A-2 in Reference 2) mole fraction that will permit horizontal propagation into compartment i.

XSMXPU(i) [R] - <Default = .55>
Maximum diluent (See Table A-2 in Reference 2) mole fraction that will permit upward propagation into compartment i.

3.2.3.10.2 Output Control Variables

See Section 5.1.5 of Reference 2 and Chapter 4 of this report for a general discussion of the usage of the output control variables described below.

DELPA [R] - (pascals) <Default = 0.>
Minimum absolute change in any compartment pressure that will result in new values of heat-transfer timestep variables being written to units UOH and UOA. Values will be written for all compartments. If this quantity is zero, then the pressure check will be a pure relative test.

DELPR [R] - <Default = .03>
Minimum relative change in any compartment pressure that will result in new values of heat-transfer timestep variables being written to units UOH and UOA. Values will be written for all compartments. If this quantity is zero, then the pressure check will be a pure absolute test.

DELTA [R] - (kelvins) <Default = 0.>
Minimum absolute change in any compartment temperature that will result in new values of heat-transfer timestep variables being written to units UOH and UOA. If this quantity is zero, then the temperature check will be a pure relative test.

DELTR [R] - <Default = .01>
Minimum relative change in any compartment temperature that will result in new values of heat-transfer timestep variables being written to units UOH and UOA. If this quantity is zero, then the temperature check will be a pure absolute test.

DELXA [R] - <Default = .001>
Minimum absolute change in any gas mole fraction that will result in new values of heat-transfer timestep variables being written to units UOH and UOA. If this quantity is zero, then the mole fraction check will be a pure relative test.

DELXR [R] - <Default = 0.>
Minimum relative change in any gas mole fraction that will result in new values of heat-transfer timestep variables being written to units UOH and UOA. If this quantity is zero, then the mole fraction check will be a pure absolute test.

DELTHT [R] - <Default = .1>
Maximum fraction of the total simulation time (TRUN) that can elapse from a previous heat-transfer timestep variable output before new values of heat-transfer timestep variables will be written to units UOH and UOA. <u>If this quantity is set to zero, then new values of heat-transfer timestep variables will be written on every heat-transfer timestep</u>.

DELVA [R] - (meters per second) <Default = .1>
Minimum absolute change in any flow junction velocity that will result in new values of flow timestep variables being written to unit UOF. If this quantity is zero, then the velocity check will be a pure relative test.

DELVR [R] - <Default = .01>
Minimum relative change in any flow junction velocity that will result in new values of flow timestep variables being written to unit UOF. If this

quantity is zero, then the velocity check will be a pure absolute test.

DELTFL [R] - <Default = .1>
Maximum fraction of the total simulation time (TRUN) that can elapse from a previous flow timestep variable output before new values of flow timestep variables will be written to unit UOF. <u>If this quantity is set to zero, then new values of flow timestep variables will be written on every flow timestep</u>.

3.2.3.10.3 Timestep Control Variables

DPRSMX [R] - (pascals) <Default = 10132.5>
Maximum absolute pressure change allowed in a compartment during a heat-transfer timestep.

DTMPMX [R] - (kelvins) <Default = 10.>
Maximum absolute temperature change allowed in a compartment during a heat-transfer timestep.

FLOMAX [R] - <Default = .95>
Maximum fraction of a compartment's gas volume that is allowed to flow out into other compartments during a flow timestep.

PCHMAX [R] - (pascals) <Default = 300.>
Maximum absolute pressure change allowed in a compartment during a flow timestep.

DTHTMN [R] - (seconds) <Default = .00001>
Minimum allowed timestep for heat-transfer calculations. This number must be greater than or equal to DTFLMN.

DTHTMX [R] - (seconds) <Default = 2.>
Maximum allowed timestep for heat-transfer calculations. This number must be greater than or equal to DTFLMX.

DTFLMN [R] - (seconds) <Default = .000001>
Minimum allowed timestep for intercompartment gas flow calculations. This number must be less than or equal to DTHTMN.

DTFLMX [R] - (seconds) <Default = 2.>
Maximum allowed timestep for intercompartment gas flow calculations. This number must be less than or equal to DTHTMX.

3.2.3.10.4 Miscellaneous Variables

NEXTRD [R] - (seconds) <Default = 1.0E+10>
The absolute time in the simulation that must be reached before additional pseudo-NAMELIST-type input can be read. This is useful for changing the values of certain parameters during the course of a run. This additional input will be read from unit UIC, must follow the $ ending this section of NAMELIST entries, and in turn must be terminated with a $ in column 1. At this point, NEXTRD can be set again, to an even later time in the simulation, so that when HECTR reaches this new time set point, more pseudo-NAMELIST-type input can be read. See also the discussion of TIMZER. As an example of the use of NEXTRD, suppose you wish to change the hydrogen ignition limits 1000 seconds into a calculation. The input would appear as follows:

```
XHMNIG = 1.0 !No combustion allowed
NEXTRD = 1000.
$End of NAMELIST INPUT
XHMNIG = 0.06 !Turn on igniters at
              !1000 seconds
$End of additional NAMELIST INPUT
```

FANS [A] - <Default = OFF>
Determines the mode of fan operation. Set this variable to

OFF	if there are no fans operating
ON	if the fans are to be turned on immediately (they will remain on for TFRUN seconds)
AUTO	if the fans are to be turned on after one of the previously specified set points (PSETF or TSETF) has been exceeded in any compartment (excluding the drywell compartments if a suppression

pool is included in the model). The fans will come on after a specified delay, DELAYF, and then remain on for TFRUN seconds.

Note that NEXTRD can be used to change the mode of fan operation (for example, from AUTO to OFF) at a specified time during a calculation.

FNCOOL [A] - <Default = OFF>
Determines the mode of fan cooler operation. Set this variable to

- OFF if the fan cooler is not operating in normal mode initially (but may later turn on in LOCA mode)
- ON if the fan cooler is initially operating in the normal mode. It will remain on for TFCRUN seconds if it does not switch to LOCA mode.

HTEXCH(i) [A] - <Default = OFF>
Determines the mode of sump heat exchanger operation. Set this variable to

- OFF if there is no heat exchanger operating for sump i
- ON if the heat exchanger for sump i is to be turned on immediately (it will remain on for THERUN(i) seconds)
- AUTO if the heat exchanger for sump i is to be turned on after one of the previously specified set points (PSETH(i) or TSETH(i)) has been exceeded in any compartment (excluding the drywell if a suppression pool is included in the model). The sump heat exchanger will come on after a specified delay, DELAYH, and then remain on for THERUN(i) seconds.

Note that NEXTRD can be used to change the mode of sump heat exchanger operation (for example, from AUTO to OFF) at a specified time in a run.

SATFLG [L] - <Default = False>
If set to TRUE, then the sprays will fail in the recirculation mode if the temperature of the sump supplying the spray water reaches saturation.

SPRAYS(i) [A] - <Default = OFF>
Determines the mode of spray operation for the ith train. Set this variable to

OFF	if train i is not operating
ON	if train i is to be turned on immediately (it will remain on for TSPRUN seconds)
AUTO	if train i is to be turned on after one of the previously specified top level actuation criteria has been met. The sprays will come on after a specified delay, DELAY, and then remain on for TSPRUN seconds.

Note that NEXTRD can be used to change the mode of spray operation (for example, from AUTO to OFF) at a specified time in a run.

CHTICE [R] - <Default = 5.>
Factor to account for basket roughness and liquid layers in the definition of the Nusselt number for an ice-condenser surface (STYPE = 4 or 5). (See Section A.2.5 and Eqs. A-54 and A-55 of Reference 2.)

COCO2 [L] - <Default = FALSE>
See description of this variable in the initial NAMELIST-type input section

HTCORL [I] - <Default = 1>
Determines correlation to use for convective heat transfer and condensation on walls and lumped mass surfaces. Set this variable to

1	for the normal heat transfer/ mass transfer analogy correlations
2	for the alternate (Uchida) correlation (see Section A.2.5 of Reference 2)

MRCHSC [I] - <Default = 0>
The number of the compartment into which external (MARCH) sources are injected. The external (MARCH) input will be read in from unit UMI. If MRCHSC is zero, then it is assumed that there are no external (MARCH) inputs.

RAD [L] - <Default = TRUE>
See discussion of this variable in the initial NAMELIST-type input section

RECIRC [L] - <Default = TRUE>
If FALSE, then the sprays will turn off after the injection phase has completed (there will be no recirculation phase).

SCDOF(i) [R] - <Default = 0.>
Surface condensation drain-off factor. This quantity is multiplied with a mass flux for surface i based on a vertical plate, laminar flow calculation to determine the condensation runoff from the surface. This factor is used only for slab and lumped-mass surfaces. (See Section A.2.5 and Eq. A-64. in Reference 2)

TIMZER [R] - (seconds) <Default = 0.>
The initial time in a HECTR run. Note that some of the HECTR variables (e.g., TDNRUP, TIMHE(i), and NEXTRD) refer to absolute times rather than time that has passed since the start of the calculation. Resetting TIMZER may also require resetting these parameters.

WFTMX(i) [R] - (meters) <Default = .001>
Maximum water film thickness resulting from condensation that is allowed on surface i. This term is used only for slab and lumped-mass surfaces (STYPE = 1 or STYPE = 2).

WFHS [R] - <Default = 0.1>
Surface condensation weighting factor (see Equation 2.14).

XWFHS [R] - <Default = 0.7>
Steam mole fraction for changing surface condensation weighting factor (see Equation 2.14).

Remember to enter a $ in column 1 at the end of the NAMELIST-type input!

3.3 Input File for the Output Processor (ACHILES)

ACHILES processes the time-dependent variable output (compartment pressures, flow junction velocities, surface temperatures, etc.) produced by HECTR. This output is divided into three categories: major heat-transfer timestep variables, flow timestep variables, and additional heat-transfer timestep variables. The values of these variables are read from the ACHILES units UHD, UHF, and UHA, respectively. ACHILES can create tables and graphs of this data. For example, consider surface temperatures. Often, the user may be interested only in the temperature histories of certain surfaces. Other times, the user may want temperature information on all surfaces. The procedures for selecting some, all, or none of the surfaces (or any other item) is explained in detail in Section 3.3.2. Following this explanation are lists of the possible variables that can be tabulated or plotted as functions of time. Prior to the input specifying which tables and graphs are to be produced, a NAMELIST-type input is required. This input can be used to change default values of various table and plot parameters.

ACHILES uses the DISSPLA graphics package [20] to produce plots. This package must reside on the user's computer system for plots to be possible. If DISSPLA is not available, then tables can still be produced, but the user will need to generate new plotting routines for the available system.

3.3.1 NAMELIST-Type Input

This section of the input is in a pseudo-NAMELIST-type format. See Section 3.1.1 for a description of the form of this input. This data is read from unit 5. Default values are provided for all of the variables in this section (as shown by the quantities within the angle brackets), and new values need be assigned only for those variables, if any, that need to be changed. Input is terminated with a dollar sign ($) placed in column 1. ACHILES input and output can be controlled using NAMELIST-type variables. The units for reading and writing data can be specified similarly to those discussed previously for HECTR in Section 3.2. In addition, NAMELIST-type variables can be used to control the amount of data printed in the tables and the format of plots. If any plotting is to be done, care should be taken that the computer word length is defined appropriately by setting either the CMPUTR or the LENWRD variable.

>>>
3.3.1.1 Input Control Variables

BATCH [L] - <Default = FALSE>
If TRUE, then all input will be echoed unless the units UOM and UOT are the

same. This will normally be desirable when running ACHILES in batch (non-interactive) mode and undesirable when running ACHILES interactively. See also CMPUTR.

CMPUTR [A] - <Default = VAX>
Type of computer on which ACHILES is running. The effects of the possible values of this variable are

CDC	sets BATCH to TRUE, UOT to 6, and sets internal variables that are affected by the computer word length (which is 10 bytes for a CDC computer)
CYBER	same as for CDC
CRAY	sets BATCH to TRUE, UOT to 6, and sets internal variables that are affected by the computer word length (which is 8 bytes for a CRAY)
VAX	sets BATCH to FALSE, UOT to 10, and sets internal variables that are affected by the computer word length (which is 4 bytes for a VAX)

The calls to the DISSPLA plot package for graph titling require knowledge of the computer word length in order to convert character-data-type titles into Hollerith, since DISSPLA is not ANSI standard FORTRAN 77 (as of January 1, 1984). These actions are desirable in the computing environment available at SNLA, but they may not be optimal at other installations.

LENWRD [I] - <Default = 4>
Computer word length in bytes. The calls to the DISSPLA plot package for graph titling require knowledge of the computer word length in order to convert character-data-type titles into Hollerith, since DISSPLA is not ANSI standard FORTRAN 77 (as of January 1, 1984). Usually, an appropriate value is 4 for DEC and IBM computers, 8 for CRAY computers, and 10 for CDC (CYBER) computers. Setting CMPUTR above will automatically set LENWRD to the correct value.

UAR [I] - <Default = 5>
The unit to which user input to ACHILES for specifying desired tables and plots is entered.

UHD [I] - <Default = 7>
The unit from which the values of major variables defined on heat-transfer timesteps are read (in unformatted READs). The HECTR output unit corresponding to UHD is UOH (which defaults to 7).

UHF [I] - <Default = 8>
The unit from which the values of majorvariables defined on flow timesteps are read (in unformatted READs). The HECTR output unit corresponding to UHF is UOF (which defaults to 8).

UHA [I] - <Default = 9>
The unit from which the values of additional variables defined on heat-transfer timesteps are read (in unformatted READs). The HECTR output unit corresponding to UHA is UOA (which defaults to 0--no output).

3.3.1.2 Output Control Variables

UOM [I] - <Default = 6>
The unit to which output messages produced by ACHILES are written.

UOT [I] - <Default = 10>
The unit to which output tables are written. See also CMPUTR above.

UAO [I] - <Default = 10>
The unit to which ACHILES summary output is written. If UOT is set to a number different than UAO, and BATCH is set to TRUE, then the ACHILES Summary information (and nothing else) will be written to UAO. This can be useful, for example, if is it desired to write the tables produced by ACHILES directly to microfiche and also create a hard copy of the ACHILES summary information.

3.3.1.3 Plot Control Variables (See Section 5.2.3 of Reference 2)

COMBXF(i)* [L] - <Default = FALSE>
If TRUE, then the mole fraction plots for all gases but nitrogen in compartment i are combined into a single graph with each mole fraction curve indicated by a different line type. Setting COMBXF(i) to TRUE will set PLTXS(i), PLTXN2(i), PLTXO2(i), PLTXH2(i), PLTXCO(i), and PLTXCD(i) to FALSE. If it is desired to plot some of the mole fractions individually, as well as on a combined plot, then the appropriate PLT variables must be reset to TRUE <u>after</u> COMBXF(i) has been set to TRUE.

LEGCXF [L] - <Default = TRUE>
If TRUE, then for combined mole fraction plots, a legend identifying the different mole fraction curves will be placed in the upper right hand corner. In some cases the legend may overlap the curves making it desirable to omit the legend. The gas species indicated by each line type as recorded in the legend are

———————— (solid)	steam	(H_2O)
—.—.—.—. (chain dot)	oxygen	(O_2)
— – — – — (chain dash)	hydrogen	(H_2)
- - - - - - - (dashed)	carbon monoxide	(CO)
. . . . (dotted)	carbon dioxide	(CO_2)

NYTIKS [I] - <Default = 5>
Number of tick marks per step to be displayed on the vertical axis of all graphs.

TRPLEX [L] - <Default = FALSE>
If TRUE, then the DISSPLA triplex (fancy, publication quality) alphabet will be used to label the graphs.

PLTDEN(i)* [L] - <Default = TRUE>
If FALSE, then the density versus time graph for compartment i will not be plotted.

PLTPRS(i)* [L] - <Default = TRUE>
If FALSE, then the pressure versus time graph for compartment i will not be plotted.

PLTSAT(i)* [L] - <Default = FALSE>
If TRUE, then an overlay of the saturation and compartment gas temperatures for compartment i will be plotted. Note that PLTTMP(i) must still be set to FALSE to eliminate the normal compartment temperature plot.

PLTTMP(i)* [L] - <Default = TRUE>
If FALSE, then the temperature versus time graph for compartment i will not be plotted.

PLTXS(i)* [L] - <Default = TRUE>
If FALSE, then the steam mole fraction versus time graph for compartment i will not be plotted. See also COMBXF(i).

PLTXN2(i)* [L] - <Default = TRUE>
If FALSE, then the nitrogen mole fraction versus time graph for compartment i will not be plotted. See also COMBXF(i).

PLTXO2(i)* [L] - <Default = TRUE>
If FALSE, then the oxygen mole fraction versus time graph for compartment i will not be plotted. See also COMBXF(i).

PLTXH2(i)* [L] - <Default = TRUE>
If FALSE, then the hydrogen mole fraction versus time graph for compartment i will not be plotted. See also COMBXF(i).

PLTXCO(i)* [L] - <Default = TRUE>
If FALSE, then the carbon monoxide mole fraction versus time graph for compartment i will not be plotted. See also COMBXF(i).

PLTXCD(i)* [L] - <Default = TRUE>
If FALSE, then the carbon dioxide mole fraction versus time graph for compartment i will not be plotted. See also COMBXF(i).

PMIN [R] - (kilopascals) <Default = 50.>
Minimum pressure displayed on the vertical scale of pressure versus time graphs.

PSTEP [R] - (kilopascals) <Default = 50.>
Pressure stepsize used on the vertical scale of pressure versus time graphs.

PMAX [R] - (kilopascals) <Defaults to an internal calculation>
Maximum pressure displayed on the vertical scale of pressure versus time graphs. If this quantity is not specified, then an appropriate value will be determined directly from the data.

TMIN [R] - (kelvins) <Default = 200.>
Minimum temperature displayed on the vertical scale of temperature versus time graphs.

TSTEP [R] - (kelvins) <Default = 200.>
Temperature stepsize used on the vertical scale of temperature versus time graphs.

TMAX [R] - (kelvins) <Defaults to an internal calculation>
Maximum temperature displayed on the vertical scale of temperature versus time graphs. If this quantity is not specified, then an appropriate value will be determined directly from the data.

*Note that plots for this variable will be produced only if this NAMELIST variable is set to TRUE and the plot is requested in the ACHILES input read from unit UAR.

3.3.1.4 Table Control Variables

SHOWPT(i) [I] - <Default = 1>
Letting n = SHOWPT(i), entries for the pressure/temperature/density/mole fraction table for compartment i will

be printed only on every nth timestep that ACHILES has read from unit UHD.

SHOWSV [I] - <Default = 1>
Letting n = SHOWSV, sump volumes will be printed only on every nth timestep that ACHILES has read from unit UHD.

SHOWWT [I] - <Default = 1>
Letting n = SHOWWT, surface temperatures will be printed only on every nth timestep that ACHILES has read from unit UHD.

SHOWHF [I] - <Default = 1>
Letting n = SHOWHF, heat and mass fluxes will be printed only on every nth timestep that ACHILES has read from unit UHD or UHA.

SHOWSR [I] - <Default = 1>
Letting n = SHOWSR, source information will be printed only on every nth timestep that ACHILES has read from unit UHD.

SHOWSY [I] - <Default = 1>
Letting n = SHOWSY, spray information will be printed only on every nth timestep that ACHILES has read from unit UHD or UHA.

SHOWIC [I] - <Default = 1>
Letting n = SHOWIC, ice-condenser information will be printed only on every nth timestep that ACHILES has read from unit UHD or UHA.

SHOWJV [I] - <Default = 1>
Letting n = SHOWJV, flow junction velocities will be printed only on every nth timestep that ACHILES has read from unit UHF.

SHOWFN [I] - <Default = 1>
Letting n = SHOWFN, fan volumetric flow rates will be printed only on every nth timestep that ACHILES has read from unit UHF.

SHOWSP [I] - <Default = 1>
Letting n = SHOWSP, suppression pool information will be printed only on

every nth timestep that ACHILES has read from unit UHF.

Remember to enter a $ in column 1 at the end of the NAMELIST type input!

3.3.2 Tables and Plots

This data is read from unit UAR (UAR is defined in Section 3.3.1.1).

For each type of table that can be produced or graph that can be plotted, it is usually necessary to specify which compartments, flow junctions, surfaces, etc., are to be included. Consider, for example, plots of compartment spray heat-removal rates. Entering an input line beginning with the word ALL will select all possible compartments. Entering an input line beginning with the word NONE will choose no compartments (and so none of these plots will be produced). Often, plots for only some compartments will be desired. These compartments are indicated by numbers read in consecutive I3 formats. For example, if the input line is

```
  1  3  4  5  6  8  9 11 12 13 14 15
```

then compartments 1, 3 through 6, 8, 9, and 11 through 15 are selected. The special symbol ==> (meaning "through") can be used as a shorthand notation so that

```
  1  3==>  6  8  9 11==> 15
```

will choose the same compartments as the previous specification (note that everything is still written in consecutive I3 formats). If in the HECTR simulation there are sprays only in the first ten compartments, then ACHILES will not produce graphs from compartments numbered 11 and above (so that graphs for compartments 11 through 15 in the above example will not appear). If there are no sprays at all in the HECTR run, then no plots of this variable will be created. Similarly, no flow junction velocity tables or graphs will be produced for a single compartment case, etc. The ACHILES input for these items are still required, however. The same comments are generally applicable to all tables and plots. Entering an input line beginning with QUIT will cause ACHILES to quit processing further input (i.e., ACHILES execution will be terminated, and no further tables or plots will be produced). If the input line begins with SKIP, then the input processing will proceed immediately to the beginning of the next section (there are three major sections under both Tables and Plots: Major Heat-Transfer Timestep Variables, Flow Timestep Variables, and Additional Heat-Transfer Timestep Variables).

If the input line begins with the word PLOT then the input processing will proceed immediately to the plotting segment of ACHILES. Lines that begin with an exclamation mark (!) are always treated as comments as is any text following an exclamation mark located anywhere in an input line.

3.3.2.1 Tables

The possible tables that can be produced, in order of required input (except when SKIPping or PLOTting), are listed below. See the discussion above for the method used to specify each line of input.

3.3.2.1.1 Major Heat-Transfer Timestep Variables (from unit UHD)

>>>
[1] For each compartment desired, display the pressure (kilopascals), temperature (kelvins), and the gas mole fractions that were present at the beginning of each timestep. Also, note when a discrete burn was occurring in each compartment by printing a T under the column labeled 'Burn?' (or F, if there was no discrete burn). In addition, display the overall gas density (kilograms per cubic meter), the total rate (kilograms per second) of hydrogen and steam injected into each compartment, and the quality of the steam injected.
>>>
[2] For each sump desired, display its volume (cubic meters) versus time.
>>>
[3] For each surface desired, display its temperature (kelvins) and note whether water was condensing on it, evaporating from it, or whether the surface was dry (indicated by a C, E, or D respectively).
>>>
[4] For each surface desired, display the liquid film thickness (meters) versus time.
>>>
[5] Display

(1) the total containment injection rates (kilograms per second) for each source gas
(2) the total accumulated masses (kilograms) of each injected source gas
(3) external (MARCH) steam and hydrogen source information (the rate [kilograms per second] that water is transferred to the ECC system; the rate [kilograms per second], quality and total accumulated mass [kilograms] of injected steam; the rate [kilograms per second] and total accumulated mass [kilograms] of injected hydrogen)

versus time. Either 'ALL' or some combination of the numbers in parentheses may be specified.

>>>
[6] If desired, display the fraction of the initial ice mass remaining in the ice condenser versus time. Either 'All' or ' 1' are valid entries.

3.3.2.1.2 Flow Timestep Variables (from unit UHF)

>>>
[7] For each flow junction desired, display the gas velocity through it (meters per second) at the beginning of each timestep and note whether the junction was closed and whether flow through the junction was choked (indicated by the two letters following the velocity--a T indicates that a condition was true and an F indicates that a condition was false).

>>>
[8] For each compartment (with a containment leak) desired, display the containment leak area (square meters), steam leak rate (kg/s), total gas leak rate (kg/s), integrated steam flow (kg), and integrated total flow (kg) for the lowest numbered leak in the compartment. (In HECTR version 1.5, it was envisioned that there would only be one leak per compartment. However, the modifications for version 1.5N give enough additional capabilities for modeling leakage that often multiple leaks are desired within a single compartment. Generally, plots are used to examine HECTR results much more often than tables. Thus, the version 1.5 logic was not modified to print tables for multiple leaks in a single compartment; the plot capabilities (See Section 3.3.3) were expanded to provide this information)

>>>
[9] For each fan connection desired, display the fan volumetric flow rate (cubic meters per second) versus time.

>>>
[10] If desired, display suppression pool information: vent gas volumetric flow rates (cubic meters per second) where 1 is the top vent, 2 is the middle vent, and 3 is the bottom vent; and vertical distances (meters) that the surface of the suppression pool is above the centerline of the bottom vent in the drywell and in the wetwell all versus time. Either 'All' or ' 1' are valid entries.

3.3.2.1.3 Additional Heat-Transfer Timestep Variables (from unit UHA)

>>>
[11] For each surface desired, display the net total heat flux to it (watts per square meter) versus time.

>>>
[12] For each surface desired, display the net radiative heat flux to it (watts per square meter) versus time.
>>>
[13] For each surface desired, display the convective heat flux (including effects due to condensation) to it (watts per square meter) versus time.
>>>
[14] For each surface desired, display the water condensation and drainage rates to/from it (kilograms per second) versus time.
>>>
[15] For each specified compartment, display the mass-evaporation rate (kilograms per second) from the sprays and the heat-removal rate (watts) by the sprays versus time.
>>>
[16] For each spray train desired, display the emitted spray drop temperature (kelvins) versus time for all of the initiating spray compartment in that train.
>>>
[17] If desired, display ice-condenser information. Values of the following variables are listed for each of the ice condenser stacks: melting rate for each of the ice surfaces (kilograms per second), total rate (kilograms per second) of water falling into the lower plenum, drain temperature (kelvins), and condensation rate (kilograms per second) on the water falling through the lower plenum atmosphere, all versus time. Either 'ALL' or ' 1' are valid entries. Note that it is not possible to specify that a table be created for only a selected stack when using a multiple-stack ice condenser.

3.3.2.2 Plots

The possible plots that can be produced, in order of required input (except when SKIPping), are listed below. See the discussion at the beginning of this section for the method used to specify each line of input.

3.3.2.2.1 Major Heat-Transfer Timestep Variables (from unit UHD)

>>>
[1] For each compartment desired, plot the pressure (kilopascals), temperature (kelvins), saturation temperature (kelvins), gas density (kilograms per cubic meter), and the mole fractions of steam, nitrogen, oxygen, hydrogen, carbon monoxide and carbon dioxide versus time.
>>>
Enter data describing the horizontal (time) axis for all graphs. <u>This input must always be entered immediately after</u>

the input to [1] above unless the input was QUIT (even if the input was NONE or SKIP).

XMIN [R] - (seconds)
Minimum time to be displayed on each graph.

XSTEP [R] - (seconds)
Timestep size used on the horizontal scale of each graph.

XMAX [R] - (seconds)
Maximum time to be displayed on each graph.

NXTIKS [I] - Number of tick marks per step to be displayed on the horizontal axis of each graph.

>>>
[2] For each sump desired, plot its volume (cubic meters) versus time.

>>>
[3] For each surface desired, plot its temperature (kelvins) versus time.

>>>
>>>
[4] For each surface desired, plot the film thickness on it (meters) versus time.

>>>
[5] Plot

(1) the total containment injection rates (kilograms per second) for each source gas
(2) the total accumulated masses (kilograms) of each injected source gas
(3) external (MARCH) steam, hydrogen, carbon monoxide, and carbon dioxide source information: the rate (kilograms per second) that water is transferred to the emergency core cooling system; the rate (kilograms per second), quality and total accumulated mass (kilograms) of injected steam; the rate (kilograms per second) and total accumulated mass (kilograms) of injected hydrogen, carbon monoxide, and carbon dioxide

versus time. Either 'ALL' or some combination of the numbers in parentheses may be specified

>>>
[6] For each compartment (with an energy source) desired, plot the energy addition rate (Watts) from external sources versus time.

>>>
[7] For each sump desired, plot the energy removal rate (Watts) due to heat exchangers versus time.

>>>
[8] If desired, plot the fraction of the initial ice mass remaining in the ice condenser versus time. Either 'ALL' or ' 1' are valid entries.
>>>
[9] For each ice surface desired, plot the mass (kilograms) versus time. (Specify the ice surface number, not the heat transfer surface number.)

3.3.2.2.2 Flow Timestep Variables (from unit UHF)

>>>
[10] For each flow junction desired, plot the velocity (meters per second) versus time.
>>>
[11] For each flow junction desired, plot the volumetric flow (cubic meters per second) versus time.
>>>
[12] For any flow junction with variable area, plot the junction area (square meters) versus time.
>>>
[13] For each containment leak desired, plot the containment leak area (square meters), steam and total gas leak rates (kilograms per second), integrated steam and total gas leakages (kilograms) versus time.
>>>
[14] For each fan connection desired, plot the volumetric flow rate through it (cubic meters per second) versus time.
>>>
[15] For each compartment desired that has a sump in it, plot the total steam addition rate due to sump boiling (kilograms per second) versus time.
>>>
[16] Plot suppression pool information

(1) top vent gas volumetric flow rate (cubic meters per second)
(2) middle vent gas volumetric flow rate (cubic meters per second)
(3) bottom vent gas volumetric flow rate (cubic meters per second)
(4) vertical distance (meters) the surface of the suppression pool is above the centerline of the bottom vent in the drywell
(5) similar to (4), except in the wetwell

versus time. Either 'ALL' or some combination of the numbers in parentheses may be specified.

3.3.2.2.3 Additional Heat-Transfer Timestep Variables (from unit UHA)

>>>
[17] For each surface desired, plot the net total heat flux to it (watts per square meter) versus time.

>>>
[18] For each surface desired, plot the net radiative heat flux to it (watts per square meter) versus time.
>>>
[19] For each surface desired, plot the convective heat flux (including effects due to condensation) to it (watts per square meter) versus time.
>>>
[20] For each surface desired, plot the condensation rate on it (kilograms per second) versus time.
>>>
[21] For each surface desired, plot the water drainage rate from it (kilograms per second) versus time.
>>>
[22] For each compartment desired, plot the mass-evaporation rate (kilograms per second) from the sprays versus time.
>>>
[23] For each compartment desired, plot the heat-removal rate (watts) by the sprays versus time.
>>>
[24] Integrated spray rates for all spray injection in all compartments

(1) integrated spray evaporation rate (kilograms)
(2) integrated heat-removal rate (joules)

versus time. Either 'ALL' or some combination of the numbers in parentheses are valid entries.
>>>
[25] For each spray train desired, plot the emitted spray drop temperature (kelvins) versus time for all of the initiating compartments in the train.
>>>
[26] For each of the ice surfaces (in an ice condenser) desired, plot its melting rate (kilograms per second) versus time. (Specify the ice surface number not the heat transfer surface number.)
>>>
[27] Plot ice-condenser information for each stack

(1) total rate (kilograms per second) of water falling into the lower plenum
(2) drain temperature (kelvins)
(3) condensation rate (kilograms per second) on water falling through the lower plenum atmosphere

versus time. Either 'ALL' or some combination of the numbers in parentheses are valid entries. Note that three plots will be created for each stack of the ice condenser.
>>>
[28] Plot fan cooler information

(1) rate of water condensation (kilograms per second) in fan cooler

(2) sensible plus latent heat transfer rate to fan cooler (watts)

versus time. Either 'ALL' or some combination of the numbers in parentheses are valid entries.

3.4 External Interface to Primary System Models (MARCH)

3.4.1 Introduction

As discussed in Section 3.2.3, HECTR can use input tables describing source terms consisting of any of the gas species treated by the code. However, if a large number of scenarios are being considered, then providing this input may become very time-consuming. Because of this problem, we have developed an interface to a primary system model that allows a much more convenient treatment of sources and ECC recirculation.

The particular interface in HECTR was developed for the MARCH code, but the same approach can be used for other primary system codes. The approach used is relatively straightforward. The primary system code simply produces a file containing the pertinent information that HECTR then reads. It is not required that the codes be intimately coupled and run in parallel. This assumes that the containment response does not affect the primary system response. The details of the interface are provided below.

3.4.2 Details of the External Interface

The HECTR subroutines IMARCH and MARCHI act as the interface for source term input provided by external primary system computer codes. These subroutines read an output file written in a specific format that has been generated by one of these codes. Normally, the user will have to modify the primary system code to create this file. This section will describe the format of the file required by HECTR and additional details regarding the usage of the external interface.

The first line of the external file is assumed to be a title identifying the contents of the file. IMARCH reads this label and then prints it out noting that this line is "FROM MARCH". IMARCH then initializes the variables for the interface. The rest of the file should consist of a time history of carbon monoxide, carbon dioxide, hydrogen and steam source terms being injected into the containment from the primary system, their corresponding enthalpies, and the rate of water being recirculated into the emergency core cooling system (ECCS) from a designated containment sump. The actual variables read by HECTR, in order, are

NTIME [R] - (seconds)
The absolute time specifying the end time for this step (see discussion below).

NDNCO [R] - (kilograms per second)
Rate of injection of carbon monoxide for this step.

NDNCO2 [R] - (kilograms per second)
Rate of injection of carbon dioxide for this step.

NDNH2 [R] - (kilograms per second)
Rate of injection of hydrogen for this step.

NDNH2O [R] - (kilograms per second)
Rate of injection of steam for this step.

NHCO [R] - (joules per kilogram)
Enthalpy of the carbon monoxide source for this step. This enthalpy is based on steam tables (i.e., the enthalpy is zero at 273.15 K).

NHCO2 [R] - (joules per kilogram)
Enthalpy of the carbon dioxide source for this step. This enthalpy is based on steam tables (i.e., the enthalpy is zero at 273.15 K).

NHH2 [R] - (joules per kilogram)
Enthalpy of the hydrogen source for this step. This enthalpy is based on steam tables (i.e., the enthalpy is zero at 273.15 K).

NHH2O [R] - (joules per kilogram)
Enthalpy of the steam source for this step. This enthalpy is based on steam tables (i.e., the enthalpy is zero at 273.15 K).

NECCRR [R] - (kilograms per second)
The rate at which water is recirculated into the emergency core cooling system from containment. This water is drawn from the spray recirculation sump (SPRSRC, defined in Section 3.2.2.12).

The external file represents a set of step functions with time as the abscissa. The value taken for each variable at a time within a given step is the value it has at the end of the step. The variables are read as needed in list-directed format in the subroutine MARCHI. MARCHI is entered on every flow timestep at the simulation time specified by the HECTR variable TIME. If TIME is greater than NTIME, then new values of the variables will be read and the old values will be saved in the variables OTIME, ODNCO, ODNCO2, ODNH2, ODNH2O, OHCO, OHCO2, OHH2, OHH2O, and OECCRR. This last action will be repeated until a value of NTIME is encountered that is greater than or equal to TIME. The new values of the variables are then used in the HECTR conservation equations until the next step is crossed. This method of choosing values is appropriate for output received from the MARCH computer code, but may have to be modified by the user for output received from other primary systems codes (for example, the user may wish to interpolate the values between OTIME and NTIME). If an end-of-file occurs, then the last values read by MARCHI will be used for HECTR times greater than the last time read into NTIME.

By default, HECTR assumes that there is no external input. This assumption can be overridden by assigning a nonzero value to the pseudo-NAMELIST variable MRCHSC (see Section 3.2.3.10.4). A positive integer is used to indicate the number of the compartment into which the external source is to be injected. A second pseudo-NAMELIST variable, UMI (see Section 3.2.1.1), specifies the unit from which the external source input is to be read. The value of this variable defaults to 1. Appendix C shows some examples of control language on various computers that can be used to access an external source file.

3.4.3 An Example External Source File

In this section, we present a sample external source file. The number of entries in the table has been greatly reduced for simplicity from what would normally be expected in a file generated by a primary system code. This external source file is the same one that was used in the sample problem presented in Section 6.2 of Reference 2. These values are fairly typical of what one would expect for a small-break LOCA in a PWR with ECC failure. Notice that the steam source starts at zero seconds, while the hydrogen source does not start until 3000 seconds later (remember that the value of a quantity over a table interval is the value that it has at the end of the interval).

```
***   EXAMPLE EXTERNAL SOURCE FILE   ***
0.0    0.  0.  0.  90.  0.  0.   0.          1.376E+06  0.
2000.  0.  0.  0.  85.  0.  0.   0.          1.339E+06  0.
```

2500.	0.	0.	0.	20.	0.	0.	0.	2.712E+06	0.
3000.	0.	0.	0.	24.	0.	0.	0.	2.845E+06	0.
4000.	0.	0.	0.1	15.	0.	0.	1.2649E+07	2.847E+06	0.
5000.	0.	0.	0.4	20.	0.	0.	5.9449E+06	2.670E+06	0.
6000.	0.	0.	0.1	6.0	0.	0.	4.1966E+06	2.617E+06	0.
7000.	0.	0.	0.05	2.0	0.	0.	3.9140E+06	2.689E+06	0.

4.0 OUTPUT DESCRIPTION

This chapter describes the changes in the HECTR and ACHILES output for version 1.5N. New error and informative messages will be listed in Section 4.1 as well as the additional variables written to the HECTR output files. The changes in the ACHILES output will be discussed in Section 4.2.

4.1 Changes in HECTR Output

The HECTR output that has been added or changed for version 1.5N is discussed in this section. The remainder of the HECTR output is discussed in Chapter 5 of Reference 2.

4.1.1 Error and Warning Messages

HECTR has many internal checks throughout the program. These checks are designed to give the user indications of trouble as it occurs and to terminate HECTR (with the usual run summary information printed) before a FORTRAN fatal error occurs. HECTR will print a message if certain fatal errors occur. Fatal errors will cause HECTR to terminate, but a traceback will be produced listing the name of each program unit that was in the calling sequence of the program unit where the error occurred. Following the traceback, a summary of the run (see Section 5.1.3 of Reference 2) up to the point where the fatal error occurred will be produced.

The error messages that can be produced by HECTR version 1.5N that were not in version 1.5 are shown below. Each message is reproduced exactly as it would appear if printed by HECTR. Integers that are determined at run time are indicted by strings of lower case m's, and n's. All of the messages identify the program unit that wrote them and have been listed alphabetically by program unit. Following each message is a short discussion of the error. This discussion may include possible causes and remedies for the error as well as an explanation of the message (if it is not obvious).

4.1.1.1 INITAL

```
*** INITAL:  TRIP NUMBER mmm REFERENCED BY LEAK NUMBER nnn
             IS NOT IN DATA SET ***
```

The indicated containment leak attempted to use a trip that was not defined in the input.

```
*** INITAL:  TABLE NUMBER mmm REFERENCED BY LEAK NUMBER nnn
             IS NOT IN DATA SET ***
```

The indicated containment leak attempted to use a table that was not defined in the input.

```
*** INITAL:  TRIP NUMBER mmm REFERENCED BY TRIP NUMBER nnn
```

IS NOT IN DATA SET ***

The indicated trip attempted to use a second trip that was not defined in the input.

*** INITAL: TRIP NUMBER mmm REFERENCED BY JUNCTION NUMBER nnn IS NOT IN DATA SET ***

The indicated junction attempted to use a trip that was not defined in the input.

*** INITAL: TABLE NUMBER mmm REFERENCED BY JUNCTION NUMBER nnn IS NOT IN DATA SET ***

The indicated junction attempted to use a table that was not defined in the input.

4.1.1.2 INPUT1

*** INPUT1: MAX ALLOWED NUMBER OF LEAK VALVES (mm), HAS BEEN EXCEEDED ***

The maximum allowed number of valve-type leaks has been exceeded by the input. This limit is controlled by the symbolic parameter NLKVAL. See Section 2.4.

*** INPUT1: MAX ALLOWED NUMBER OF STEAM VENTS (mm), HAS BEEN EXCEEDED ***

The maximum allowed number of steam vent type leaks has been exceeded by the input. This limit is controlled by the symbolic parameter NSVEN. See Section 2.4.

*** INPUT1: MAX ALLOWED NUMBER OF POINTS IN STEAM VENT TABLE (mm), HAS BEEN EXCEEDED ***

The maximum allowed number of points in a steam vent closing table has been exceeded by the input. This limit is controlled by the symbolic parameter NSVPTS. See Section 2.4.

*** INPUT1: MAX ALLOWED NUMBER OF VALVES (mm) HAS BEEN EXCEEDED ***

The maximum allowed number of valve type junctions has been exceeded by the input. This limit is controlled by the symbolic parameter NVALV. See Section 2.4.

*** INPUT1: MAXIMUM ALLOWED NUMBER OF COMPARTMENTS ORIGINATING SPRAYS (mm) HAS BEEN EXCEEDED IN TRAIN nn ***

The maximum allowed number of compartments in which sprays originate for the indicated spray train has been exceeded by the input. This limit is controlled by the symbolic parameter NSC. See Section 2.4.

***INPUT1: ONLY 1 LAYER IS ALLOWED FOR SURFACES IN HECTR VERSION 1.5N BECAUSE THERE IS AN ERROR IN THE MULTILAYER FORMULATION ***

As noted in Section 1.2, there is an error in the multilayer surface formulation in this version of HECTR and, therefore, surfaces are constrained to a maximum, of one layer.

4.1.1.3 INPUT2

*** INPUT2: MAX ALLOWED NUMBER OF TRIPS (mm)
HAS BEEN EXCEEDED ***

The maximum allowed number of valve trips has been exceeded by the input. This limit is controlled by the symbolic parameter NTRIP. See Section 2.4.

*** INPUT2: MAX ALLOWED NUMBER OF TRIP TESTS (mm)
HAS BEEN EXCEEDED ***

The maximum allowed number of tests per trip has been exceeded by the input. This limit is controlled by the symbolic parameter NTTST. See Section 2.4.

*** INPUT2: MAX ALLOWED NUMBER OF TABLES (mm)
HAS BEEN EXCEEDED ***

The maximum allowed number of tables has been exceeded by the input. This limit is controlled by the symbolic parameter NTABL. See Section 2.4.

*** INPUT2: MAX ALLOWED NUMBER OF TABLE ENTRIES (mm)
HAS BEEN EXCEEDED ***

The maximum allowed number of data pairs for a table has been exceeded by the input. This limit is controlled by the symbolic parameter NPTAB. See Section 2.4.

4.1.2 Informative Messages

HECTR will write informative messages whenever important events occur. The informative messages that can be produced by HECTR version 1.5N that either were not in version 1.5 or have been modified are shown below. Each message is reproduced exactly as it would appear if printed by HECTR.. Real numbers, integers, and character strings that are determined at run time are indicted by strings of lower case x's and y's; k's, m's, and n's; and a's, respectively. The messages are listed below alphabetically by topic. Following each message is a short discussion of its meaning.

*** STATUS OF SPRAY TRAIN mm CHANGED TO aaaa AT xxxx.xxx SECONDS ***

Each spray train can either be ON, OFF, or in AUTO mode. At the time indicated, the status of train mm will be changed to the mode designated by aaaa.

SPRAY TRAIN mm WILL BE ACTIVATED AT xxxx.xxx SECONDS
BASED ON CRITERIA nn IN COMPARTMENTS:
kkkk ...

When in AUTO mode, a spray train can be actuated based on pressure and temperature setpoints in designated compartments. This message identifies the particular spray train that is being activated, the time that spray flow will actually occur (which can be later that the current time), and the compartments where the setpoints were exceeded.

4.1.3 Additional Output on Data Files

Three different output files can be produced that contain the transient values of HECTR variables. These files are produced by writing the values of selected variables to the HECTR units UOH, UOF, and UOA (using unformatted write statements). The file written on unit UOH contains basic information about the HECTR calculation, followed by the transient values of variables describing compartment and surface conditions. The variables that describe the flows between compartments are written on unit UOF. The third file, written on unit UOA, contains additional HECTR variables that are used less often than the variables on the other two files, but are needed in some analyses. The transient variables written to each of the three units are listed in Table 4-1.

The three HECTR output files are processed by the computer program ACHILES to produce tables and plots of the desired variables. ACHILES can be run immediately after HECTR (during the same computer job), or the HECTR output files can be saved and ACHILES can process them during a subsequent job.

4.2 ACHILES Output

Only minor changes were made to the header section of the ACHILES output for version 1.5N. The message indicating the mode of spray operation was expanded to indicate the status for each train. In addition, the messages "(TRIP VALVE)" will be printed below type 7 junctions in the junction summary section. The remainder of the ACHILES summary output is unchanged and is discussed in Chapter 5 of Reference 2.

Table 4.1

HECTR Output Variables

Unit UOH
Introductory information
Time (s)

For each compartment:
- Pressure (kPa)
- Temperature (K)
- Mole fractions:
  - Steam
  - Nitrogen
  - Oxygen
  - Hydrogen
  - Carbon monoxide*
  - Carbon dioxide*
- Burning status for discrete burns
- Density (kg/m^3)
- Saturation temperature (K)

For each sump:
- Volume (m^3)

For each surface:
- Wall temperature (K)
- Condensation mode
- Film thickness (m)

If there is an ice condenser:
- For each ice surface:
  - Mass (kg)
- Fraction of ice still in ice bed

If there is a MARCH source:
- ECC flow rate (kg/s)
- Steam injection:
  - Flow rate (kg/s)
  - Accumulated mass (kg)
  - Quality
- Hydrogen injection:
  - Flow rate (kg/s)
  - Accumulated mass (kg)
- Carbon monoxide injection:
  - Flow rate (kg/s)
  - Accumulated mass (kg)
- Carbon dioxide injection:
  - Flow rate (kg/s)
  - Accumulated mass (kg)

---

* If included in simulation

Table 4.1 (Continued)

HECTR Output Variables

Unit UOH (cont.)

For each injected gas:
- Total injected flow rate (kg/s)
- Total accumulated mass (kg)

For each compartment that water is injected into:
- Steam injection rate (kg/s)
- Water injection rate (kg/s)

For each compartment that hydrogen is injected into:
- Hydrogen injection rate (kg/s)

For each compartment that carbon monoxide is injected into:
- Carbon monoxide injection rate (kg/s)

For each compartment that carbon dioxide is injected into:
- Carbon dioxide injection rate (kg/s)

For each compartment with an energy source:
- Rate of energy addition (W)

For each sump:
- Rate of heat transfer to heat exchanger (W)

Unit UOF

Time (s)

For each junction:
- Velocity (m/s)
- Volumetric flow rate (m^3/s)
- Choking flag

For each junction with variable area:
- Junction area (m)

For each fan:
- Flow rate (m^3/s)

If there is a Mark III suppression pool:
- For each vent:
  - Gas flow rate (m^3/s)
- Drywell side water level (m)
- Wetwell side water level (m)

For each containment leak:
- Area (m^2)
- Steam flow rate (kg/s)
- Total gas flow rate (kg/s)
- Net steam leaked (kg)
- Net gas leaked (kg)

Table 4.1 (Continued)

HECTR Output Variables

For each containment leak:
    Volumetric flow rate (m^3/s)

For each compartment with a sump in it:
    Rate of steam addition due to sump boiling (kg/s)

<u>Unit UOA</u>
Time (s)

For each surface:
    Net heat flux (W/m^2)
    Radiative heat-flux incident on surface (W/m^2)
    Condensation rate (kg/s)
    Water runoff rate (kg/s)

For each spray train:
    For each initiating spray compartment in the train
        Injection temperature (K)

For each compartment with sprays:
    Spray mass evaporation rate (kg/s)
    Heat-transfer rate (W)

Total (integrated) steam addition due to sprays (kg)

Total (integrated) spray heat transfer (J)

Total condensation rate in fan coolers (kg/s)

Total heat removal rate from fan coolers (W)

If there is an ice condenser:
    For each ice column:
        Condensation rate on water in lower plenum (kg/s)
        Sum of ice melting rates and condensation on ice surfaces (kg/s)
        Drain temperature (K)

For each ice surface:
    Melting rate (kg/s)

5. EXAMPLE PROBLEM

In this chapter, an example problem for the N Reactor confinement is presented. This example utilizes most of the new features present in HECTR Version 1.5N. Reference 2 contains additional sample problems for Version 1.5. Further, Reference 3 contains copies of some of the input decks used in the calculations presented there. Reference 3 also contains additional information regarding the N Reactor confinement that will clarify the description below. The calculation presented in this chapter should be considered as an example only and not representative of any particular accident scenario.

5.1 N Reactor Confinement Description

5.1.1 General Description

In this section, we will give a brief description of the overall confinement arrangement, the leak and junction configuration and the fog spray systems. This information was taken from References 13, 14, and 15.

The N Reactor is located on the DOE's Hanford Reservation in southeastern Washington State, northwest of the city of Richland. The facilities occupy a 90-acre site on the south bank of the Columbia River. Among the many buildings at the site, three are of interest for these calculations: 1) the 105 building - the reactor building, 2) the 109 building - the heat exchanger building, and 3) the 117 building - the filter building. Figure 5.1 shows the general layout of these buildings (primary confinement zone only).

There are five N Reactor building zones, three of which are related to the confinement of radionuclides during accidents. For these calculations, only the primary confinement zone (Zone 1) is of interest. The primary confinement zone encloses the reactor, the primary coolant system, and the reactor gas system. The N Reactor uses a confinement rather than a containment system because of the large exclusion zone and other design features which still allow 10 CFR 100 guidelines to be met. The initial steam burst from a postulated accident is released to the external environment through steam vents and then, when the pressure subsides, the steam vents are closed and a filtered vent is opened. The entire primary confinement zone is designed to withstand internal pressures of + 5.0 psig (136 kPa).

5.1.2 105 Building

The general arrangement of the primary confinement zone for the reactor building is shown in Figure 5.2. The reactor core is a cubical volume in the center of the building. Enclosed pipe barrier spaces hang on the front and rear faces of the reactor with wing-like extensions on each side. The graphite gas space, inside the reactor, and the thermal shields are cooled by the graphite and shield cooling system which circulates cooling water from the graphite and thermal shields to the auxiliary room heat exchangers in the 109 building. A 3 psid (20.7 kPad) blowout panel separates the graphite gas space from the rear pipe barrier space. Each pipe barrier space has 18 access holes on top and 18 on bottom. Half the holes are on the left side; half are on the right side. When in operation, the lower holes are bolted shut from the inside. The top holes have hatch covers which are just laid over the hole and will, therefore, open upwards if the differential pressure is great enough (>.21 psid or 1.45 kPad).

The piping of the primary coolant system enters from the bottom of the 109 building, goes up and over the top of the reactor on the left and right sides, down into the front pipe barrier space, through the reactor into the rear pipe barrier space, down and back into the 109 building to the steam generators.

The volume on each side of and underneath the reactor is not in the primary confinement zone, but is in the secondary confinement zone (zone II). From the side the primary confinement zone looks like an inverted U (See Figure 5.2). The zone starts in the lower front, extends up and over the top of the reactor and excluded side volumes, and down to the lower back. There is a wall separating the front and rear of the building with a two-foot high opening extending all the way across the top.

On the top of the building are three rooms (608, 605, and 604). The front and rear rooms (608 and 604, respectively) are machinery rooms which hold the pipe barrier thermal shields which are raised when the reactor is shut down. There is a rectangular hole in the floor of each room for the shield to enter. The center room (605) is the exhaust to the filter building. It has nine equally spaced holes in the floor allowing gas to pass up into the room and then out the three ventilation system confinement exhaust valves to the filter building.

In order to allow gas expansion, there are cross-vents between the 105 and 109 building. There are eight vents, four on each side at the 50-foot elevation. One of the four cross-vents on the right side is normally left full open. The other seven open up if there is greater than a 1.5" wg differential pressure (373 Pad) from the 109 to 105 building. There are shear pins which shear at 2.25 psid (15.5 kPad) differential pressure from the 105 to 109 building. Therefore, if the pressure is greater in the 109 building, the cross-vents act like variable area doors with the area depending on differential pressure. If the pressure is higher in the 105 building, they act as blowout panels.

On the roof of the 105 building are two steam vents and two vacuum breakers. There is one steam vent and one vacuum breaker on each side of the reactor building. On the left side is the special steam vent. On the right is the regular steam vent. The steam vents have covers which rupture at 1.25 psig (109.9 kPa) and 2.0 psig (115.1 kPa), respectively, for the special and regular vent. They have closure valves which close after the initial pressure transient has passed, as described in the section on actuation logic (Section 5.1.5). The vacuum breakers are operated by reactor building pressure against a weight lever. They begin opening at -.25 psig (99.6 kPa) and are full open at -.5 psig (97.9 kPa).

In the rear of the 105 building, at the bottom, is a junction to the fuel transfer pool. This junction is constructed as a "banana" wall. There is a discharge basin into which the rear wall penetrates to a depth which will allow for a $\geq$5 psig ($\geq$ 136 kPa) seal between the inside and outside surfaces of the pool.

After a postulated accident occurs, the fog spray system comes on and injects 8,570 gpm (.54 m**3/s) in order to condense steam, reduce pressure, and scrub fission products. The sprays are auto actuated at 10" wg (103.8 kPa) in the reactor building. The spray nozzles are located on the ceiling of the reactor building so that all areas in the building except for the region directly over and in front of the reactor are covered. The spray region, therefore, forms a U shaped region around the top of the reactor building starting in the front left, going down the left side, across the back, and up the right side to the front.

5.1.3 The 109 Building

The general arrangement of the primary confinement zone for the heat exchanger building is shown in Figure 5.3. The heat exchanger building is divided into six steam generator cells, an auxiliary cell, a pressurizer penthouse, a large pipe gallery, and an extension to the pipe gallery added when steam generator cell six was added.

The pipe gallery is a large open volume with the piping for the graphite and thermal shield, and primary coolant systems entering into the bottom third of the gallery and then going to the auxiliary and steam generator cells, respectively. Located in the pressurizer penthouse situated on top of the pipe gallery is a pressurizer which is connected to the hot leg. When a sixth steam generator cell was added, an extension to the pipe gallery was made. The wall at the left end of the pipe gallery has four large open doors connecting the two regions.

There are fourteen regular steam vents and two vacuum breakers located in the pipe gallery. The steam vents are similar to the regular steam vent in the reactor building, blowing open at +2.0

psig (115.1 kPa), and closing at some later time as described in Section 5.1.5. There are seven steam vents located across from the steam generator cell five, four across from steam generator cell one, and two across from steam generator cell six. The two vacuum breakers are similar to those in the reactor building and are located across from steam generator cell one.

The cross-vents from the reactor building enter at the top of the pipe gallery.

The pipe gallery also has a fog spray system. The spray nozzles are equally spaced across the top of the building so that complete coverage is obtained. The drop sizes are larger than those in the reactor building (1690 vs. 1400 or 1100 microns). The system is auto-actuated at 10" wg (103.8 kPa) pressure in the heat exchanger building as described in Section 5.1.5 and injects a total of 1200 gpm (.076 m**3/s).

The steam generator cells each have two steam generators. There are three large ducts at the top of each cell and a sump at the bottom. These open into the pipe gallery. There are sliding doors which can cover the upper doors on any cell isolating it so that maintenance can be performed on one cell while the reactor is in operation. These doors will be randomly covering one of the steam generator cells. Each sump has 10" (.254 m) of water in it when the reactor is in operation and 300 gpm (.019 m**3/s) sump pumps start automatically if the level reaches 12" (.305 m). The sumps are 11 feet (.335 m) deep and 21 feet (6.4 m) wide and extend along the 50-foot width (15.24 m) of the face of the cell.

The auxiliary cell is similar to the steam generator cells but does not have a sump. Instead, it has a small open door about half way up the wall separating it from the pipe gallery. There are four heat exchangers for cooling the graphite and thermal shields in the cell.

There is a fog spray system in the steam generator cells, but actuation of this system is manual. There are no procedures for turning the steam generator sprays on in an accident and so these were not modeled. The auxiliary cell does not have any sprays.

5.1.4 The 117 Building

The general arrangement of the ducts to the filter building, the filter building, and the vent stack are shown in Figure 5.4. Only the filtered release mode is shown. As described in Section 5.1.5, all other 105 and 109 building HVAC fans and ducting isolate upon receipt of a 2" wg (101.8 kPa) signal and do not reopen. The gas exits from the 105 building through three 72" butterfly valves (confinement exhaust valves) down an exhaust duct to the filter building, through the "D" cell, into another duct, and then out the vent stack.

The confinement exhaust valves are isolated early in the accident when pressure exceeds 2" wg (101.8 kPa) in the reactor building. Later, these valves reopen if pressure is <3" wg (102 kPa) and 205 s have elapsed (see Section 5.1.5). At this time, filter cells A and B are in operation. According to procedures, the filters are manually realigned when pressure in zone I falls below 2" wg (101.8 kPa). The "D" cell is put on line and the other cells are isolated. Since the normal filters are not in operation for very long, we only modeled the "D" cell.

5.1.5 Actuation Logic for Vents and Sprays

There are four actuation circuits which affect the vents and sprays: 1) the 105 confiner circuit, 2) the 109 confiner circuit, 3) the 105 spray circuit, and 4) the 109 spray circuit. The most complicated is the 105 confiner circuit which we will discuss first. All the circuits are illustrated in Figure 5.5.

5.1.5.1 The 105 Confiner Circuit

At 2" wg (101.8 kPa), four pressure switches in the 105 building, acting in 2/4 logic, isolate the 105 HVAC system (including the confinement exhaust valves to the filter building) and start three 150 s timers. There is a redundant set of four pressure switches which will also isolate the 105 HVAC system upon start of the ECC systems. When 2/3 of the 150 s timers time out, two things happen: 1) three 55 s timers will start, and after 2/3 of the 55 s timers time out and if 2/4 pressure switches in the 105 building indicate <3" wg (102 kPa), then the confinement exhaust valves to the filter building will open, and 2) if primary system pressure is <575 psig (<4 MPa), all fourteen regular steam vents will close. After the confinement exhaust valves open, the special steam vent closes. If pressure in the 105 building ever increases to >15" wg (105 kPa), then a 2/4 pressure switch logic will reclose the confinement exhaust valves. The valves will reopen if pressure falls back below 15" wg (105 kPa). Note, however, that once the special or regular steam vents close, they will <u>not</u> automatically reopen.

5.1.5.2 The 109 Confiner Circuit

At 2" wg (101.8 kPa), the 109 building HVAC will be isolated. The logic acts like a 2 out of 7 coincidence circuit where one pressure switch in the pipe gallery and one pressure switch in any one of the steam generator cells will trip the circuit. There is an A and a B train. There are some additional combinations of cell pressures which will trip the logic, but these were not modeled since they are redundant and would not affect the calculations. If the ECC systems start, they will also result in isolating the 109 building HVAC.

5.1.5.3 The 105 Spray Circuit

Four pressure switches arranged in 2/4 logic will auto-start the 105 building fog spray system if pressure exceeds 10" wg (103.8 kPa) in the 105 building.

5.1.5.4 The 109 Spray Circuit

Using the same pressure switches and logic of the 109 Confiner Circuit (Section 5.1.5.2), the spray circuit will auto-start the 109 fog spray system (only in the pipe gallery) if pressure exceeds 10" wg (103.8 kPa) in the 109 building.

5.2 Model Description

The 5-compartment model discussed below is similar to that presented in Reference 3. While this model lumps large volumes of the primary confinement zone, the logic and characteristics of all the leaks, vents, and junctions are modeled in the same manner as in the more detailed 15 and 38-compartment model presented in Reference 3. The 5-compartment model is most useful for checkout and scoping calculations.

Figure 5.6 shows the overall layout of the 5-volume model and identifies all the leaks, vents, and junctions. The leaks and vents are numbered L1 to L11; the junctions are numbered J1 to J7.

The reactor building is divided into two volumes: the front (volume 1) and the rear (volume 2). The front volume includes the front pipe barrier space, room 608, and room 605, the exhaust to the filter building inside the confinement exhaust valves. The rear volume includes the rear pipe barrier space, the graphite gas space, and room 604.

The two vacuum breakers makeup 4, the regular steam vent is leak 5, the special steam vent is leak 11, and there are two leaks (10 and 9) which represent small leakages from the front and rear, respectively. Junction 1 is the two-way open junction at the top of the wall separating the front and rear volumes. Junction 2 represents the three confinement exhaust valves to the filter building. Junction 5 is the open cross-vent between the 105 and 109 buildings. Junction 6 is made up of the seven normally closed cross-vents between the 105 and 109 buildings.

The heat exchanger building (109) is also divided into two volumes; the pipe gallery (volume 3) and the steam generator and auxiliary cells (volume 4). The pipe gallery volume includes the extension added when steam generator cell 6 was added.

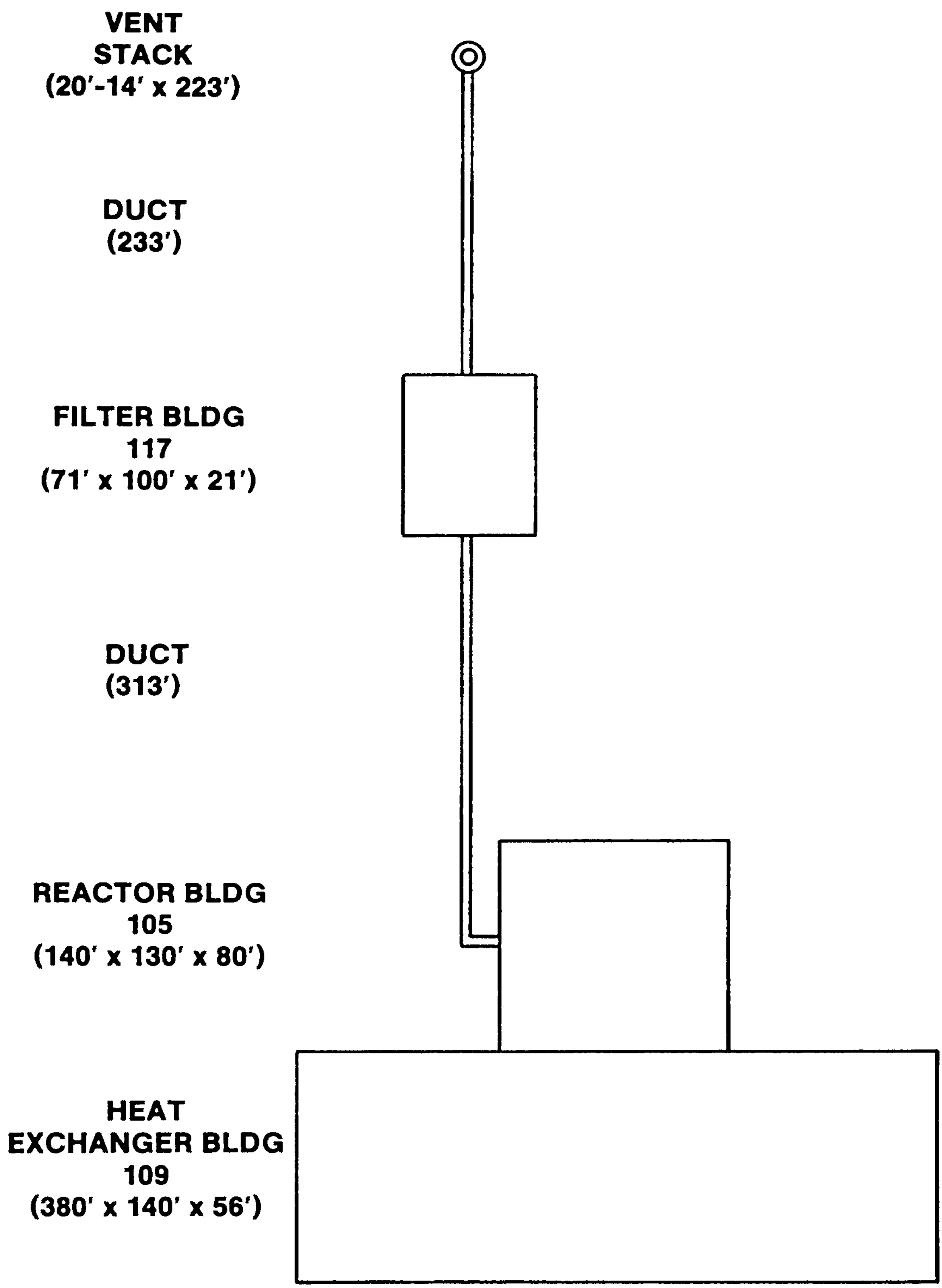


Figure 5.1. General Arrangement of N Reactor Buildings

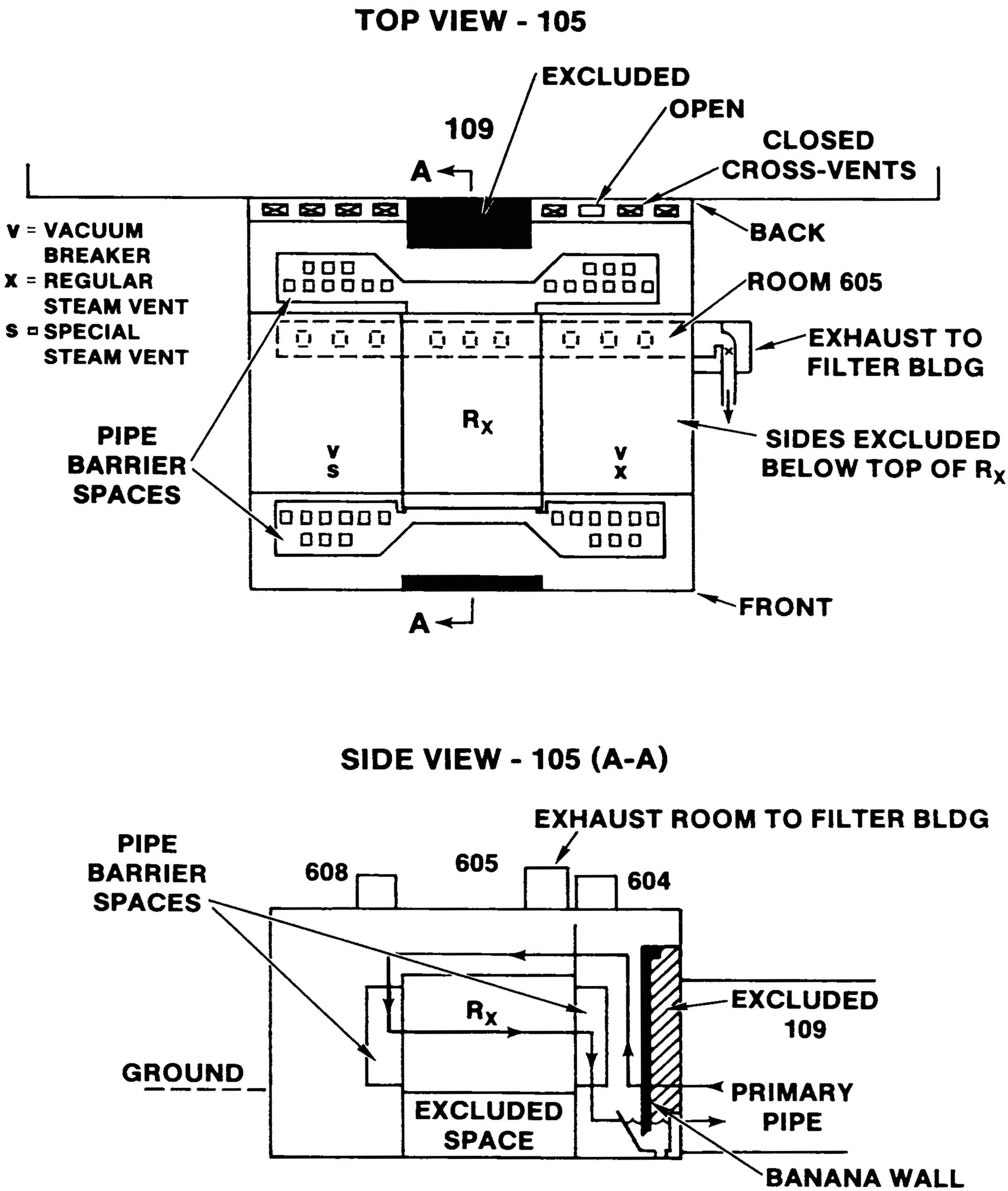


Figure 5.2. Reactor Building - 105

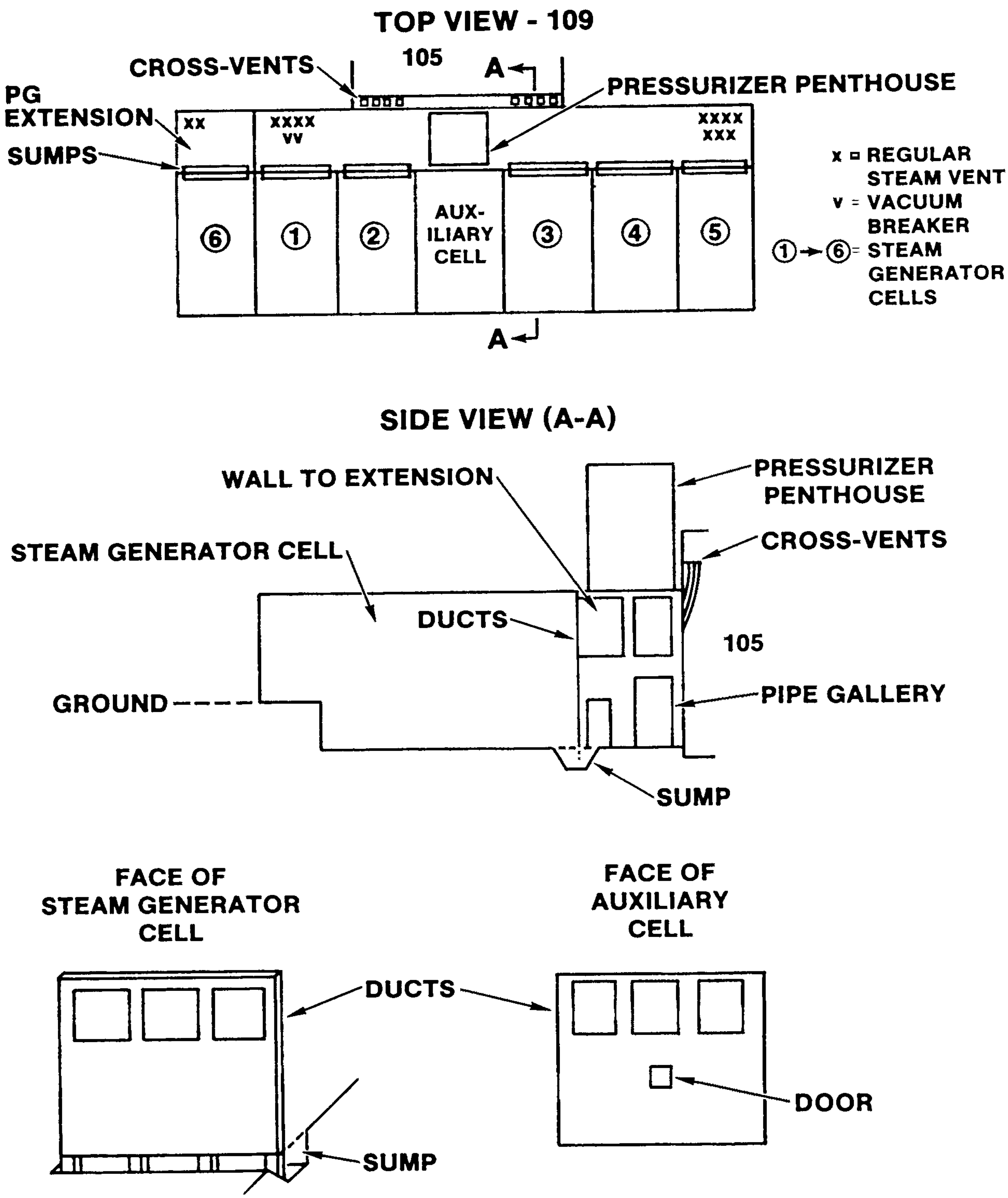


Figure 5.3. Heat Exchanger Building - 109

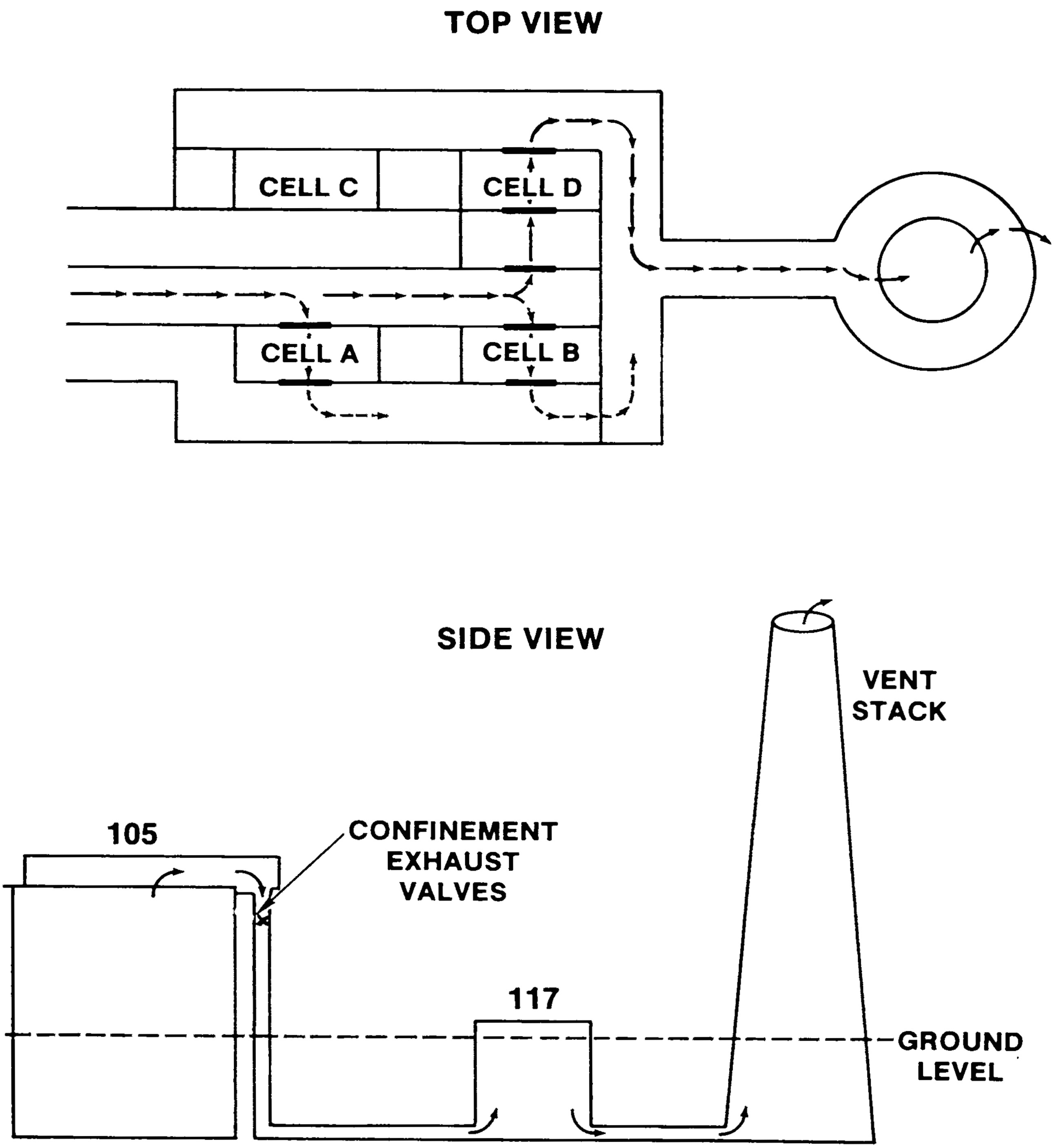


Figure 5.4. Filter Building and Vent Stack - 117

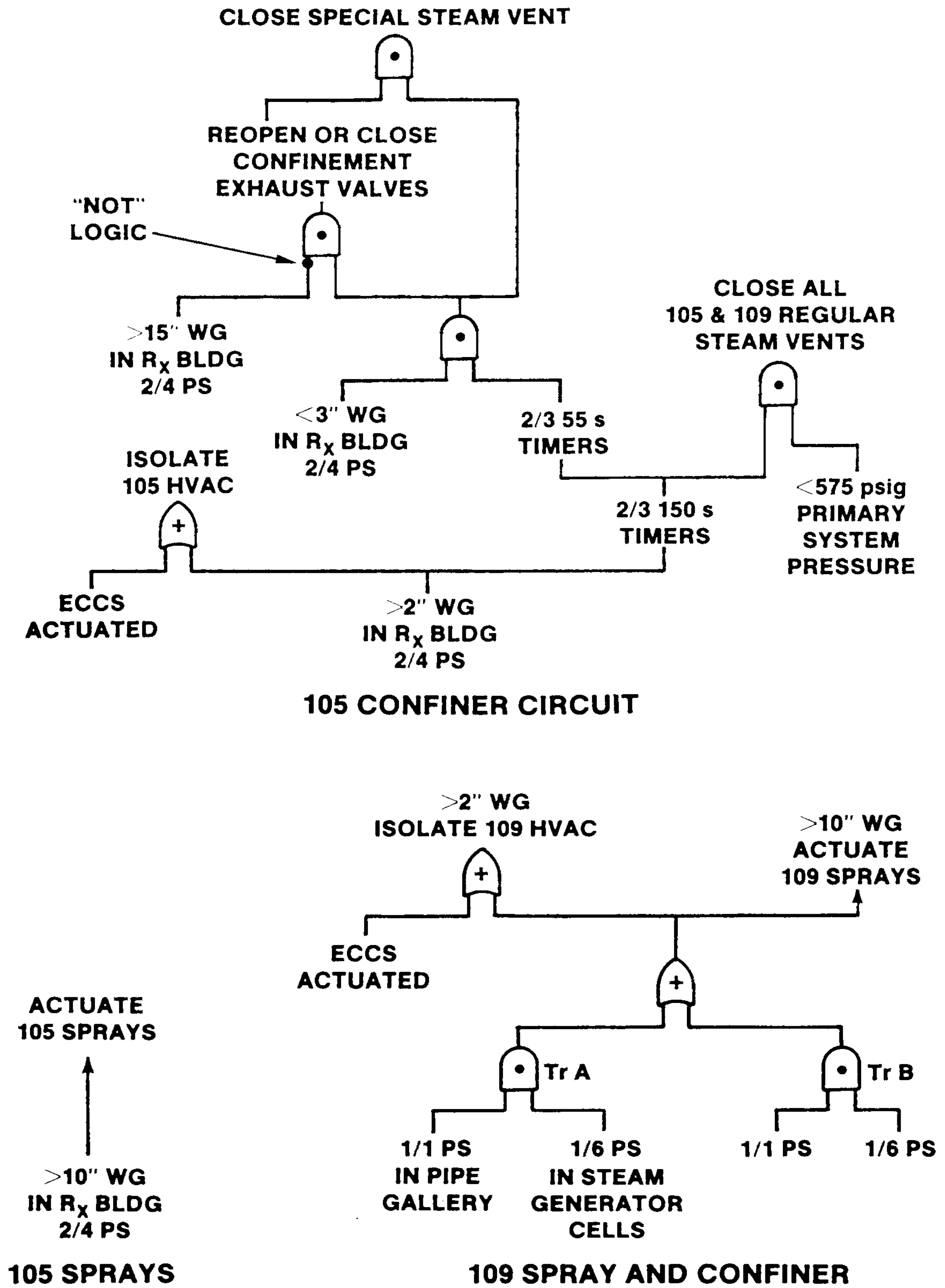


Figure 5.5. Actuation Logic for Vents and Sprays

Leaks 2, 3, and 6 are small leakages from the steam generator cells (L2 and L3) and the pipe gallery (L6). Leak 7 represents the 13 regular steam vents in the pipe gallery. Leak 8 represents the two vacuum breakers in the pipe gallery. Junction 3 represents the 21 ducts from the pipe gallery to the top of the steam generator and auxiliary cells (3 per cell). Junction 4 is the door to the pipe gallery halfway up the face of the auxiliary cell. Junction 7 represents the 6 sumps connecting the pipe gallery to the six steam generator cells.

The filter building, vent stack, and connecting ducts are volume 5. Leak 1 is the two-way open exhaust to the atmosphere.

The fog spray systems in the 105 and 109 buildings spray uniformly into volumes 1 and 2 for the 105 system and volume 3 for the 109 system. The systems are adjusted to spray the correct amount of water into each volume.

There are several important limitations to note concerning this model:

1) The top ducts on one steam generator are normally blocked by sliding doors, since the reactor normally operates with only five of the six steam generator cells in operation. In our model, all ducts are modeled as open.

2) We modeled the filter building assuming only the spare filter cell "D" was operating. When the confinement exhaust valves reopen at 3" wg (102 kPa), cells "A" and "B" will be operating. But the operator is directed to open cell "D" and isolate cells "A" and "B" when pressure drops to 2" wg (101.8 kPa) which, in fact, occurs a very short time later. Since conditions are not changing very rapidly at this time, the slight difference in flow coefficients due to the differing volumes, etc. will not have a significant effect. The one filter can adequately handle the flow at this time.

3) Due to insufficient information at the time the model was constructed, we modeled the 109 pressure as also actuating the timers in the 105 confiner circuit. However, since the buildings both exceed 2" wg (101.8 kPa) pressure within a fraction of a second of each other for the large blowdowns being analyzed, this makes no practical difference in the time of operation of the regular and special steam vents and the confinement exhaust valves.

4) Several alternate actuation paths were not modeled for actuation of the 109 building isolation and sprays. Because any of these alternate paths will have the same effect on the timing of events that the modeled path has, only one path needed to be modeled.

5) Actuation of the emergency core cooling systems (ECCS), which also actuates portions of the 105 and 109 confiner circuits, was not modeled. Since the confinement pressure exceeds 2" wg (101.8 kPa) almost immediately (i.e., < .1 s) and, since the ECCS actuation should also take place immediately, the primary confinement zone was assumed to be isolated initially for all of our calculations. If some time elapsed before isolation, this would tend to reduce the peak pressure somewhat, depending on the time necessary to isolate. This would not affect the hydrogen transport, which occurs after this time.

6) We assumed that primary system pressure would always be below 575 psig after the blowdown, since the only cases analyzed are a postulated large break. This means that the regular steam vents will always close after the 150 s timers time out.

7) The confinement exhaust valves to the filter building were modeled as reclosing after their initial opening at 205 s if the pressure increased above 15" wg (105 kPa) and reopening if the pressure dropped back to below 3" wg (102 kPa). Better information, obtained later, shows that they reopen if pressure falls back below 15" wg (105 kPa). This only affects burn calculations since the pressure spike may result in the vent closing and then reopening after the burn is over and the pressure decreases. This will not affect the burn itself and will have little effect after the burn, since the pressure will fall almost immediately back to 3" wg (102 kPa) anyway.

8) The sump pumps for the steam generator cell sumps were not modeled. For long term spray operation or a pipe break within a steam generator cell, blockage of the sump junction will occur without sump pump operation.

9) The 5-volume model is clearly inadequate to model the details of hydrogen transport.

5.3 Case Description

The example problem treats a large pipe break within the pipe gallery (compartment 3). The steam blowdown rate is a modification of the NUSAR hypothetical accident sequence [13]. The hydrogen injection rate has been arbitrarily selected to produce sufficient hydrogen to result in a burn. The hydrogen is also injected into compartment 3. The vents, vacuum breakers, and sprays have been set to operate as discussed in previous sections. The default hydrogen ignition limit of 7% is used in this calculation.

N REACTOR
5-VOLUME MODEL

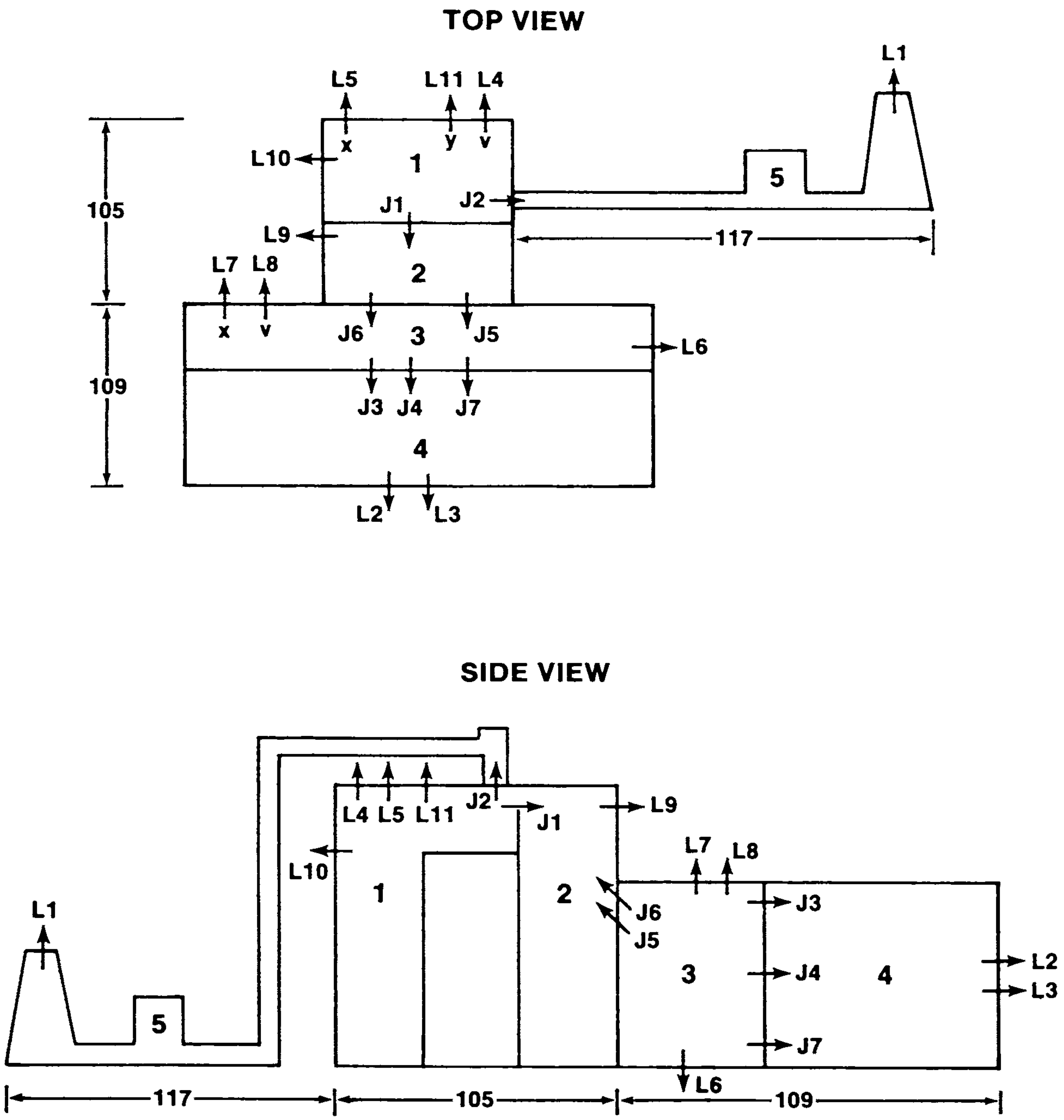


Figure 5.6. 5-Volume Model

5.3.1 HECTR Input

The HECTR input for this problem is listed below.

```
! NAMELIST TYPE INPUT
UOA = 9
CMPUTR = CRAY
$ END OF INITIAL NAMELIST INPUT
!*********************************************
! PROBLEM GEOMETRY AND CONTAINMENT DESCRIPTION
!*********************************************
N REACTOR$

THIS IS A 5 VOLUME N REACTOR DECK FOR EXAMPLE PURPOSES.
THIS CALCULATION DOES NOT REPRESENT ANY PARTICULAR SCENARIO.

ALL SI UNITS




5 ! NUMBER OF COMPARTMENTS
!
! FOR EACH COMPARTMENT: AN ID, THE VOLUME (M**3), ELEVATION (M), FLAME
! PROPAGATION LENGTH (M), NUMBER OF SURFACES, AND INTEGERS
! SPECIFYING WHICH SUMP TO DUMP EXCESS WATER (FROM SUPERSATURATION)
! INTO AND WHICH SUMP THE SPRAYS FALL INTO.
!
C1-FRONTRXBLD
11243. 9.9  19.8  4 1 1
C2-REARRXBLD
11543. 5.7  19.8  4 2 2
C3-PIPE-GALL
21507. 3.04 57.9  3 3 3
C4-6SG-AUXCELLS
45067. 3.32 15.24 3 3 3
C5-FILTERBLD
3881.  8.35 141.3 2 0 0
!
! FOR EACH SUMP: SUMP NUMBER, MAXIMUM VOLUME (M**3), SUMP NUMBER THAT
! THIS SUMP OVERFLOWS TO
!
1 16.9   0  ! SUMP 1 IS UNDERNEATH THE ELEVATOR IN FRONT RX BLDG. WHEN
            ! IT FILLS WATER FLOWS ONTO THE FLOOR AND INTO DRAINS. IT IS
            ! THEN REMOVED FROM THE REACTOR BUILDING.
!
2 413.   0  ! SUMP 2 IS THE BANNANA WALL. IT HAS A VERY LARGE VOLUME SINCE
            ! IT CONNECTS TO THE FUEL POOL; HOWEVER, WE NEGLECT THAT HERE
            ! AND CALCULATE THE VOLUME IN THE CAVITY ONLY. SINCE WHEN IT
            ! OVERFLOWS, THE WATER GOES TO THE DRAINS AND IS REMOVED FROM
            ! THE RX BLDG, THE EFFECT IS THE SAME AS IF WE INCREASED THE
            ! VOLUME BUT DID NOT ADD IT TO THE ROOM VOLUME.
```

```
!
3 3000. 0  ! THERE ARE 6 SUMPS WHICH WE TREAT AS ONE. THE OVERFLOW VOLUME
           ! USED HERE IS LARGER THAN THE REAL VOLUME=1497 SINCE WE WANT
           ! THE WATER TO BEGIN FILLING UP THE PIPE GALLERY AND STEAM
           ! GENERATOR CELLS.
$
!

! FOR EACH SURFACE: TYPE OF SURFACE, MASS OF SURFACE (KG), AREA OF
! SURFACE (M**2), CHARACTERISTIC LENGTH (M), SPECIFIC HEAT (J/KG/K),
! EMISSIVITY, INTEGER INDICATING WHICH SUMP THE CONDENSATE GOES INTO.
! FOR SLABS (STYPE = 1), THE NUMBER OF LAYERS IN THE SURFACE, AND FOR
! EACH, THE THICKNESS (M), THERMAL DIFFUSIVITY (M**2/S), AND THERMAL
! CONDUCTIVITY (W/M/K).  FINALLY, THE NODING INFORMATION AND BOUNDARY
! CONDITIONS ARE SPECIFIED (0'S INDICATE HECTR WILL DETERMINE
! THE VALUES INTERNALLY). NOTE THAT SOME OF THE NUMBERS SET TO 1.
! ARE NOT USED FOR THAT SURFACE TYPE.
!
! C1 SURFACES
!
SUMP1
3 15000. 24.55  4.16  1. .94 1
CONC1
1 1. 4143.3 24.3  1. .9  1
1
.3 1.6E-6 2.39
0 0. 0. 0.
CONC1H
1 1. 139.8  9.1   1. .9  1
1
.3 1.6E-6 2.39
0 0. -1.  477.
STEEL1
2 333336. 1597. 1. 531.7 .7 1
!
! C2 SURFACES
!
SUMP2
3 400800. 42.6 5.03 1. .94 2
CONC2
1 1. 4438.6 24.3 1. .9 2
1
.3 1.6E-6 2.39
0 0. 0. 0.
CONC2H
1 1. 139.8 9.1 1. .9 2
1
.3 1.6E-6 2.39
0 0. -1. 505.
STEEL2
2 357665.6 1454. 1. 531.7 .7 2
!
! C3 SURFACES
```

```
!
SUMP3
3 45090. 284.3 1.83 1. .94 3
CONC3
1 1. 7562. 15.83 1. .9 3
1
.3 1.6E-6 2.39
0 0. 0. 0.
STEEL3
2 576146.2 2340. 1. 531.7 .7 3

!
! C4 SURFACES
!
SUMP4
3 45090. 284.3 1.83 1. .94 3
CONC4
1 1. 14810.7 15.4 1. .9 3
1
.3 1.6E-6 2.39
0 0. 0. 0.
STEEL4
2 1282600. 5364.1 1. 531.7 .7 3
!
! C5 SURFACES
!
CONC5
1 1. 1742.7 68. 1. .94 0
1
.3 1.6E-6 2.39
0 0. 0. 0.
STEEL5
2 243071.5 4907.3 1. 531.7 .7 0
!
!
! CONTAINMENT LEAKAGE INFORMATION
!
! NUMBER OF LEAKS, NUMBER OF PRESSURE AND TEMPERATURE-DEPENDENT
! LEAKAGE CURVES
!
! NOL  NOP  NOT
  11    1    0
! LEAK COMPARTMENT, TEMPERATURE-DEPENDENT LEAKAGE CURVE, PRESSURE-
! DEPENDENT LEAKAGE CURVE, CONTAINMENT FAILURE FLAG, CONTAINMENT
! FAILURE CRITERION, CONTAINMENT FAILURE AREA (M**2), LEAK ELEVATION
! (M), LEAK LOSS COEFFICIENT, L/A FOR LEAK (1/M)
!
! COMP  T CURVE  P CURVE  NCF    CRIT  AREA  ZJI  FLI    LA
! FILTERED RELEASE FROM STACK.
   5      0        0       1       0.   14.3  61.6  1.0   .01
! LEAKS FROM SG CELLS.
   4      0        0       1       0.   .187  -4.9  17.14 .01
   4      0        0       1       0.   .005  10.7  1.0   .01
```

```
! VACUUM BREAKER FOR RX BLDG.
 1      0           -1     0   -1723.    1.3  17.8  1.6    .01
! VACUUM BREAKER OPENS AT -1723 DIFF PRESS FULL OPEN AT -3446
! REGULAR STEAM VENT IN RX BLDG.
 1      0           0      5  115111.  2.63  17.8  1.74   .01
! VENT CLOSES AFTER 2 IN WG PRESSURE +150 SEC.
!    OPEN  CLOSE  OPEN   TYPE   CLOSE  TYPE
!    TRIP  TRIP   TABLE  TABLE  TABLE  TABLE
      24    16     4      1      6      1
!LEAK FROM PG TO OUTSIDE.
 3      0           0      1       0.   .003  -4.9  1.0    .01
! REGULAR STEAM VENTS IN PG (13).
 3      0           0      5  115111. 34.18  10.9  3.01   .01

! VENT CLOSES AFTER 2 IN WG PRESSURE +150 SEC.
!    OPEN  CLOSE  OPEN   TYPE   CLOSE  TYPE
!    TRIP  TRIP   TABLE  TABLE  TABLE  TABLE
      23    16     4      1      6      1
! VACUUM BREAKER IN PG.
 3      0           -1      0     -1723.    1.3  10.9  1.6    .01
! LEAK FROM REAR RX BLDG.
 2      0           0      1       0.   .003  12.2  1.0    .01
! LEAK FROM FRONT RX BLDG.
 1      0           0      1       0.   .003  12.2  1.0    .01
! SPECIAL STEAM VENT IN RX BLDG.
 1      0           0      5  109941.  2.63  17.8  1.74   .01
! VENT CLOSES AFTER 2 IN WG +205 SEC + <3 IN WG.
!    OPEN  CLOSE  OPEN   TYPE   CLOSE  TYPE
!    TRIP  TRIP   TABLE  TABLE  TABLE  TABLE
      15    1      4      1      5      1
!
! TABLE FOR OPENING VACUUM BREAKERS
!
! HYSTERESIS FLAG AND ENTRY TO NORMALIZE TO
1    1
! DIFFERENTIAL PRESSURE ENTRIES (PA)
0. 10.  100.  1000.  1723.  2153.75   2584.5   3015.25  3446. 3876.75
! FLOW AREAS (M**2)
1.E-8 1.E-8 1.E-8 1.E-8 1.E-8  .325      .65         .975     1.3    1.3
! HYSTERESIS CONVERSION FACTORS
0.   0.   0.   0.   0.   0.   0.   0.   0.   0.
!
! FLOW JUNCTION DATA: COMPARTMENT ID'S, TYPE OF CONNECTION, FLOW
! AREA (M**2), LOSS COEFFICIENT, L/A RATIO (1/M), RELATIVE POSITION OF
! COMPARTMENTS, AND JUNCTION ELEVATION (M).
! ADDITIONAL INFORMATION IS PROVIDED FOR JUNCTION TYPE 7.
!
! FROM FRONT TO REAR RX BLDG.
1    2    1  24.2  1.395  .01   0    17.53
! TO FILTER BLDG FROM RX BLDG (FILTER VENT).
1    5    7  7.04 66.26  .01   0    19.74
!  OPEN TRIP  CLOSE TRIP  BLOWN TRIP  ABLOWN
       1           2           3         0.
```

```
!  OPEN TABLE  TYPE TABLE  CLOSE TABLE TYPE TABLE
       1           1           2         1
! DUCTS FORM PG TO SG&AUX CELLS.
3    4    1  333.6 1.0   .01   0    8.32
! AUX CELL DOOR.
3    4    1  3.25  2.0   .01   0    2.98
! OPEN CROSS VENT REAR RX BLDG TO PG.
3    2    1  2.37  2.0   .01   1    15.24
! VARIABLE CROSS VENT REAR RX BLDG TO PG.
3    2    7  16.58 2.0   .01   1    15.24
!  OPEN TRIP  CLOSE TRIP  BLOWN TRIP  ABLOWN
       9          3          10        12.88
!  OPEN TABLE TYPE TABLE  CLOSE TABLE TYPE TABLE
       3          2          3          2
! CROSS VENT BETWEEN REAR RX BLDG (2) AND PG (3)
! 16.58 IS THE FULL OPEN AREA FROM 3 TO 2 AND 12.88

! IS THE FULL OPEN AREA FROM 2 TO 3.  15513 IS THE DP (PA)
! TO SHEAR THE PIN AND OPEN THE DOOR FROM 2 TO 3.
!
! SUMP BETWEEN PG AND SG CELLS
! ELEV=-6.4M;AREA=243.24-.1728*VOL(ADDED)
3      4         6         243.24        2.0      .01      0      -6.4
!    MIN VOL   MAX VOL  SUMP   BLOWOUT
      90       1497.8     3       0
$ END OF JUNCTIONS
$ NO ICE CONDENSER
$ NO SUPPRESSION POOL
$ NO FANS
$ NO FAN COOLER
 !
 ! BEAM LENGTH AND VIEW FACTOR MATRICES
 !
 ! BEAM LENGTHS
 !
  6.854734       6.854734       6.854734       6.854734
 12*0.0
  6.854734       6.854734       6.854734
 12*0.0
  6.854734       6.854734
 12*0.0
  6.854734
 12*0.0
  6.840296       6.840296       6.840296       6.840296
  8*0.0
  6.840296       6.840296       6.840296
  8*0.0
  6.840296       6.840296
  8*0.0
  6.840296
  8*0.0
  7.600914       7.600914       7.600914
  5*0.0
```

```
   7.600914        7.600914
   5*0.0
   7.600914
   5*0.0
   7.930027        7.930027        7.930027
   2*0.0
   7.930027        7.930027
   2*0.0
   7.930027
   2*0.0
   2.100992        2.100992
   2.100992
 !
 ! VIEW FACTORS
 !
  0.0000000E+00  0.7046309       2.3775108E-02  0.2715940
  12*0.0
  0.7016890      2.3675844E-02  0.2704601
  12*0.0

  2.3675842E-02  0.2704601
  12*0.0
  0.2704601
  12*0.0
  0.0000000E+00  0.7357934       2.3174856E-02  0.2410318
   8*0.0
  0.7305974      2.3011198E-02  0.2393296
   8*0.0
  2.3011200E-02  0.2393296
   8*0.0
  0.2393296
   8*0.0
  0.0000000E+00  0.7636841       0.2363159
   5*0.0
  0.7417577      0.2295309
   5*0.0
  0.2295310
   5*0.0
  0.0000000E+00  0.7341188       0.2658812
   2*0.0
  0.7237737      0.2621344
   2*0.0
  0.2621344
   2*0.0
  0.2620601      0.7379398
  0.7379399
!
! NUMBER OF SPRAY TRAINS
2
! FOR TRAIN 1 ( IN RX BLDG C1 AND C2).
!
! NUMBER OF SOURCE COMPARTMENTS
2
```

```
! SOURCE COMPARTMENT, INJECTION TEMPERATURE (K), FLOW RATE (M**3/S),
! NUMBER OF DROP SIZES; FOR EACH DROP SIZE: FREQUENCY AND DIAMETER
! (MICRONS)
1 293.15 .26  2
.49   1400.
.51   1100.
2 293.15 .28  2
.65   1400.
.35   1100.
! FOR SPRAY CARRYOVER, THE SOURCE AND RECEIVING COMPARTMENTS AND THE
! FRACTION CARRIED OVER
!
$
! SPRAY COMPARTMENT AND SPRAY FALL HEIGHT (M)
1  12.65
2  24.1
$
!
! SPRAY ACTUATION CRITERIA FOR THIS TRAIN
!
! NUMBER OF TOP-LEVEL CRITERIA IN "OR" CONFIGURATION
2

! FOR EACH TOP CRITERIA, NUMBER OF 2ND-LEVEL CRITERIA IN "AND"
! CONFIGURATION, AND FOR EACH 2ND-LEVEL CRITERION,
! NUMBER OF COMPARTMENTS TO TEST AND, FOR EACH
! COMPARTMENT TO TEST, THE COMPARTMENT ID AND THE PRESSURE (PA)
! AND TEMPERATURE (K) SETPOINTS.  FINALLY, THE NUMBER OF
! COMPARTMENTS THAT MUST MEET THE SETPOINTS FOR THE CRITERIA
! TO BE MET
!
! TEST COMPARTMENT 1 AND 2 AND ACTUATE IF EITHER IS TRUE "OR".
!
! TEST COMPARTMENT 1 FOR 10 IN WG.
1
1
1 103813.3 0.
1
! TEST COMPARTMENT 2 FOR 10 IN WG.
1
1
2 103813.3 0.
1
!
! DELAY TIME FOR SPRAYS TO START AFTER ACTUATION AND TIME FOR
! SPRAYS TO RUN AFTER STARTING
44. 1.0E10
!
! FOR TRAIN 2 (IN PG ).
!
! NUMBER OF SOURCE COMPARTMENTS
1
! SOURCE COMPARTMENT, INJECTION TEMPERATURE (K), FLOW RATE (M**3/S),
```

```
! NUMBER OF DROP SIZES; FOR EACH DROP SIZE: FREQUENCY AND DIAMETER
! (MICRONS)
3 293.15 .076  1
1.0  1690.
! FOR SPRAY CARRYOVER, THE SOURCE AND RECEIVING COMPARTMENTS AND THE
! FRACTION CARRIED OVER
!
$
! SPRAY COMPARTMENT AND SPRAY FALL HEIGHT (M)
3  15.8
$
!
! SPRAY ACTUATION CRITERIA FOR THIS TRAIN
!
! NUMBER OF CRITERIA IN "OR" CONFIGURATION
1
! FOR EACH TOP CRITERIA, NUMBER OF 2ND-LEVEL CRITERIA IN "AND"
! CONFIGURATION, AND FOR EACH 2ND-LEVEL CRITERION,
! NUMBER OF COMPARTMENTS TO TEST AND, FOR EACH
! COMPARTMENT TO TEST, THE COMPARTMENT ID AND THE PRESSURE (PA)
! AND TEMPERATURE (K) SETPOINTS.  FINALLY, THE NUMBER OF
! COMPARTMENTS THAT MUST MEET THE SETPOINTS FOR THE CRITERIA
! TO BE MET
!
! TEST COMPARTMENT 3 (PG) "AND" 4 (SG CELLS)

1
2
3 103813.3 0.
4 103813.3 0.
2
!
! DELAY TIME FOR SPRAYS TO START AFTER ACTUATION AND TIME FOR
! SPRAYS TO RUN AFTER STARTING
44.  1.0E10
! SPRAY HEAT EXCHANGER INFORMATION
$ NO SPRAY RECIRC
$ NO SUMP HEAT EXCHANGERS
!
600. ! SIMULATION TIME (S).
!
! INITIAL CONDITIONS
!
! GAS TEMPERATURE (K), PARTIAL PRESSURES OF STEAM, NITROGEN, OXYGEN,
! AND HYDROGEN (PA), CONVECTIVE GAS VELOCITY (M/S)
! TEMP  STEAM    N2     O2      H2    CONV GAS VEL
  339.  20500. 63850. 16975.    0.     .3
  339.  20500. 63850. 16975.    0.     .3
  322.  9350.  72660. 19315.    0.     .3
  322.  9350.  72660. 19315.    0.     .3
  322.  9350.  72660. 19315.    0.     .3
! INITIAL CONDITIONS FOR LEAKS
! TATM, PPATM(1-4)
```

```
300.  9400. 72621. 19304. 0.
!
! SOURCE DATA
!
! STEAM AND WATER
! COMPARTMENT, SOURCE MODE, TEMPERATURE (NOT USED FOR MODE=3),
! AND INTEGER INDICATING SOURCE IS NOT INJECTED INTO A SUMP
   3            3                477.    0
! TIME(S)  RATE(KG/S)  ENTHALPY(J/KG)
   0.0        0.0        9.0156E5
   0.1      16349.2      8.9179E5
   0.2      17620.2      8.9225E5
   0.4      18327.8      8.9272E5
   0.6      18465.6      8.9272E5
   1.0      18293.3      8.9295E5
   1.5      18282.4      8.9318E5
   2.0      18141.8      8.9388E5
   3.0      17964.4      8.9807E5
   5.0      17190.2      9.2714E5
   6.0      17003.3      9.5343E5
   7.0      16060.7      9.8529E5
   8.0      14970.3      1.0188E6
   9.0      14533.0      1.0516E6
  10.0      13689.3      1.0814E6
  12.0      11281.7      1.1290E6
  15.0      9411.10      1.1737E6
  20.0      8951.10      1.2221E6
  25.0      7414.40      1.2560E6

  30.0      5597.30      1.2837E6
  35.0      3980.70      1.3405E6
  40.0      2624.50      1.4593E6
  43.6      1808.00      1.4763E6
  45.0      2296.10      1.3707E6
  48.4      3859.10      1.0623E6
  50.0      4327.20      9.9739E5
  55.0      4388.00      9.7645E5
  59.0      4201.20      9.6901E5
  60.0      3568.80      1.0439E6
  62.0      3632.30      1.0123E6
  64.0      2805.00      1.1265E6
  66.0      2339.60      1.2023E6
  70.0      1996.70      1.2288E6
  75.0      983.400      1.7184E6
  78.0      1219.30      1.4335E6
  80.0      1246.50      1.4882E6
  84.0      743.000      1.9273E6
  87.0      825.530      1.7368E6
  90.0      840.050      1.6582E6
  93.0      844.580      1.5896E6
  99.0      879.060      1.4775E6
 106.0      876.790      1.4233E6
 112.0      808.300      1.4570E6
```

```
 118.0     702.160     1.5145E6
 124.0     699.440     1.5545E6
 134.0     361.060     2.4214E6
 145.0     146.060     2.6633E6
 150.0     64.4100     2.6865E6
 156.0     10.8860     2.7028E6
 156.5      0.0        2.7028E6
3600.0      0.0        2.7028E6
$
$
! NO NITROGEN SOURCES
$
! NO OXYGEN SOURCES
$
! HYDROGEN
! COMPARTMENT, SOURCE MODE, SOURCE TEMPERATURE (K),
! AND INTEGER INDICATING SOURCE IS NOT INJECTED INTO A SUMP
    3          -1                477.   0
!    TIME(S)       RATE(KG/S)
        0.              0.
      250.              0.
      250.              2.
      350.              2.
      350.              0.
      1.E10             0.
$
$
$ NO WATER REMOVAL FROM SUMPS
$ NO COMPARTMENT ENERGY SOURCES
$ NO CONTINUOUS BURNING COMPARTMENTS
!

! TRIP LOGIC FOR JUNCTIONS
!
! FALSE TRIP SET TO FALSE AT -10 SEC.
! TRIP  TYPE  LOCK IN  NUM TESTS
   3    -4      1        1
! TIME TEST
!   TRIP TEST  TIME
       0       -10.
$
! PRESSURE CHECK 2 IN WG IN RX BLDG C1 & C2 "OR" LOGIC.
! TRIP  TYPE  LOCK IN NUM TESTS
   4     1      2       1
! PRESSURE TEST
!  COMP   PRESS
     1    101821.
     2    101821.
$
! PRESSURE CHECK 2 IN WG IN PG &SG CELLS "AND" LOGIC.
! TRIP  TYPE  LOCK IN NUM TESTS
   5     1      2       2
```

```
! PRESSURE TEST
!  COMP   PRESS
     3    101821.
     4    101821.
$
! OR PRESSURE CHECKS IN RX BLDG AND PG &SG.
! TRIP  TYPE  LOCK IN  NUM TESTS
   6     5      1        1
! TRIP TEST
! TRIP  DUMMY
   4     0.
   5     0.
$
! TIMER (STARTS AFTER TRIP 6).
! TRIP  TYPE  LOCK IN  NUM TESTS
  16     6      1        1
! TIME TEST
!   TRIP    TIME
      6      150.
$
! TIMER (STARTS AFTER TRIP 16).
! TRIP  TYPE  LOCK IN  NUM TESTS
  7      6      1        1
! TIME TEST
!   TRIP    TIME
     16      55.
$
! PRESSURE TO OPEN FILTER VENT AND CLOSE SPECIAL STEAM VENT IF < 3 IN WG.
! TRIP  TYPE  LOCK IN  NUM TESTS
  8     -1      2        2
! PRESSURE TEST
!   COMP   PRESS
      1    102071.
      2    102071.
$

! TIMER + PRESSURE CHECK.
! TRIP  TYPE LOCK IN  NUM TESTS
  1      5     2        2
! TRIP TEST
!  TRIP   DUMMY
     7     0.
     8     0.
$
! PRESSURE TO OPEN SPECIAL STEAM VENT.
! TRIP  TYPE LOCK IN  NUM TESTS
  12     1     1        1
! PRESSURE TEST
!  COMP    PRESS
     1    109941.
$
! PRESSURE TO OPEN REGULAR STEAM VENTS IN PG.
! TRIP  TYPE LOCK IN  NUM TESTS
  17     1     1        1
```

```
! PRESSURE TEST
!  COMP    PRESS
    3    115111.
$
! PRESSURE TO OPEN REGULAR STEAM VENT IN RX BLDG.
! TRIP  TYPE LOCK IN  NUM TESTS
  18     1    1         1
! PRESSURE TEST
!  COMP    PRESS
    1    115111.
$
! LOCK IN TEST 1 AND CLOSE SPECIAL STEAM VENT.
! TRIP  TYPE LOCK IN  NUM TESTS
  13     5    1         1
! TRIP TEST
!   TRIP   DUMMY
     1     0.
$
! SET TO OPPOSITE OF TEST 1.
! TRIP  TYPE LOCK IN  NUM TESTS
  14    -5    2         1
! TRIP TEST
!   TRIP   DUMMY
    13      0.
$
! OPEN SPECIAL STEAM VENT (ONLY IF NOT ALREADY OPENED AND CLOSED).
! TRIP  TYPE LOCK IN  NUM TESTS
  15     5    2         2
! TRIP TEST
!  TRIP  DUMMY
    14    0.
    12    0.
$
! LOCK IN TEST 16 AND CLOSE REGULAR STEAM VENTS.
! TRIP  TYPE LOCK IN  NUM TESTS
  21     5    1         1
! TRIP TEST

!   TRIP   DUMMY
     16     0.
$
! SET TO OPPOSITE OF TEST 1.
! TRIP  TYPE LOCK IN  NUM TESTS
  22    -5    2         1
! TRIP TEST
!   TRIP   DUMMY
    21     0.
$
! OPEN REGULAR STEAM VENT IN C3 (ONLY IF NOT ALREADY OPENED AND CLOSED).
! TRIP  TYPE LOCK IN  NUM TESTS
  23     5    2         2
! TRIP TEST
```

```
!  TRIP  DUMMY
    22    0.
    17    0.
$
! OPEN REGULAR STEAM VENT IN C1 (ONLY IF NOT ALREADY OPENED AND CLOSED).
! TRIP  TYPE LOCK IN  NUM TESTS
  24    5     2        2
! TRIP TEST
!  TRIP  DUMMY
    22    0.
    18    0.
$
! RECLOSE PRESSURE CHECK FOR FILTER VENT AT 15 IN WG.
! TRIP  TYPE LOCK IN  NUM TESTS
  2     1     2        1
! PRESSURE TEST
!  COMP    PRESS
     1    105055.
     2    105055.
$
! TRUE TRIP SET TO TRUE AT -10 SEC.
! TRIP  TYPE LOCK IN  NUM TESTS
  9     4     1        1
! TRIP TEST
!   TRIP TEST   TIME
        0       -10.
$
! BLOWOUT OF RX BLDG TO  PG VENT.
! TRIP  TYPE LOCK IN  NUM TESTS
  10   -2     1        1
! PRESSURE TEST JUNTION 6
!  TRIP TEST   PRESS
      6       -15513.
$
$
! TABLES FOR JUNCTIONS
!
! OPEN TABLE FOR FILTER VENT
1
!   TIME  %OPEN
      0.   0.

     10.   1.
$
! CLOSE TABLE FOR FILTER VENT
2
!   TIME  %OPEN
      0.   1.
     10.   0.
$
! OPENING TABLE FOR RX BLDG TO  PG VENT
3
```

```
!  DIFF PRESS  %OPEN
       0.         0.
     373.         0.
     622.         1.
$
! OPEN TABLE FOR SPECIAL AND REGULAR STEAM VENT .
4
!   TIME  %OPEN
     0.     1.
$
! CLOSING TABLE FOR SPECIAL VENT.
5
!   TIME  %OPEN
     0.    1.0
    15.    0.0
$
! CLOSING TABLE FOR REGULAR STEAM VENT.
6
!   TIME  %OPEN
     0.    1.0
    25.    0.0
$
$
! INITIAL WALL TEMPERATURES
!
2*339
1*477
3*339
1*505
1*339
8*322.
!
! NAMELIST TYPE INPUT
!
SPRAYS=AUTO
$
```

5.3.2 ACHILES Input

The input for the output processor ACHILES is shown below. A portion of the requested output is presented in Sections 5.4 and 5.5.

```
CMPUTR=CRAY   ! ACHILES IS BEING RUN ON A CRAY
COMBXF=TRUE   ! COMBINE MOLE FRACTION PLOTS INTO A SINGLE GRAPH
PLTDEN=FALSE  ! DO NOT PLOT GAS DENSITIES
PLTSAT=TRUE   ! PLOT SATURATION CURVE ON GAS TEMP PLOTS
PLTTMP=FALSE  ! NO ADDITIONAL GAS TEMP PLOTS
$
```

```
! **********
! * TABLES *
! **********
!
! MAIN HEAT TRANSFER TIMESTEP VARIABLES
!
  3           ! COMPARTMENT GAS CONDITIONS
NON         ! SUMP VOLUMES
NON         ! SURFACE TEMPERATURES
NON         ! FILM THICKNESSES
NON         ! SOURCES
NON         ! ICE FRACTION
!
! FLOW TIMESTEP VARIABLES
!
NON         ! JUNCTION FLOWS
NON         ! CONTAINMENT LEAKS
NON         ! FAN FLOWS
NON         ! SUPPRESSION POOL VENT FLOWS AND LEVELS
!
! ADDITIONAL HEAT TRANSFER TIMESTEP VARIABLES
!
NON         ! NET HEAT FLUXES
NON         ! RADIATIVE HEAT FLUXES
NON         ! CONVECTIVE HEAT FLUXES
NON         ! MASS DRAINING TO SUMPS AND SURFACE CONDENSATION RATES
NON         ! SPRAY EVAPORATION AND HEAT TRANSFER RATES
NON         ! SPRAY TEMPERATURE
NON         ! ICE CONDENSER INFORMATION
!
! **********
! * PLOTS  *
! **********
!
! MAIN HEAT TRANSFER TIMESTEP VARIABLES
!
ALL        ! COMPARTMENT GAS CONDITIONS
0. 100. 600. 4    ! XMIN, XSTEP, XMAX, NXTIKS
ALL               ! SUMP VOLUMES
ALL               ! WALL TEMPERATURES
ALL               ! FILM THICKNESS
ALL               ! SOURCES
NON               ! ENERGY SOURCES
NON               ! SUMP HEAT EXCHANGERS
NON               ! ICE FRACTION
NON               ! MASS OF ICE SURFACES
!
! FLOW TIMESTEP VARIABLES
!

NON               ! JUNCTION VELOCITIES
ALL               ! JUNCTION VOLUMETRIC FLOW RATES
ALL               ! JUNCTION AREAS
```

```
  1   4   5   7   8 11       ! CONTAINMENT LEAKS
NON              ! FAN FLOWS
NON              ! SUMP FLASHING RATES PER COMPARTMENT
NON              ! SUPPRESSION POOL VENT FLOWS AND LEVELS
!
! ADDITIONAL HEAT TRANSFER TIMESTEP VARIABLES
!
NON              ! NET HEAT FLUX
NON              ! RADIATION
NON              ! CONVECTION
NON              ! CONDENSATION RATE
NON              ! SURFACE DRAINING RATES
NON              ! SPRAY EVAPORATION RATES
NON              ! SPRAY HEAT TRANSFER RATES
NON              ! INTEGRATED SPRAY EVAPORATION AND HEAT TRANSFER
NON              ! SPRAY TEMPERATURE
NON              ! ICE MELTING RATES
NON              ! ICE CONDENSER LOWER PLENUM INFORMATION
NON              ! FAN COOLER INFORMATION
```

5.4 Results

In this section we will discuss the results of the example problem. A listing of the printed output from HECTR and ACHILES is presented in Section 5.5. Figures 5.7, 5.8, and 5.9 show the steam, liquid, and hydrogen sources, respectively. The split between steam and liquid is based on a flashing calculation in HECTR. As can be seen from the figures, the initial blowdown lasts about 150 s, and about 200 kg of hydrogen are injected over the time interval from 250 to 350 s.

The initial blowdown produces a peak pressure of 124.6 kPa, as shown in Figure 5.10. During this blowdown, the filter building is isolated as shown by the response of junction 2 in Figure 5.11. However, as shown in Figures 5.12, 5.13, and 5.14, the steam vents open to limit the pressurization during the blowdown. These vents close soon after the blowdown ends, based on the associated timers. When the special steam vent receives its signal to close, junction 2 recieves a signal to open, as illustrated in Figure 5.11. By the time junction 2 reopens, the containment pressure has been completely relieved through the steam vents and condensation has begun, resulting in inflow through the filter building. As shown in Figures 5.15 and 5.16, this condensation is also sufficient to cause the vacuum breakers to open. The blowdown also trips the sprays, leading to actuation at 44 s. The main effect of the sprays is to increase the condensation rate.

Hydrogen begins entering compartment 3 at 250 s and reaches a concentration of 7% at about 322 s, as shown in Figure 5.17. Because of the high steam concentration (54.7%), a very slow burn is initiated which lasts until 516 s. The burn initially causes a slight pressurization which peaks at about 350 s (see Figure 5.10). The pressure is then relieved through the filter building at a rate sufficient to more than cope with the burn. In fact, the vacuum breakers reopen partway through the burn (see Figures 5.15 and 5.16). As more cold air is brought in and the steam concentration decreases, some repressurization is then predicted near the end of the burn. This overall behavior is due to the very slow nature of the burn as a result of high steam concentrations (near the inerting level). Normally, one would expect to see a single large pressure spike as a result of a deflagration.

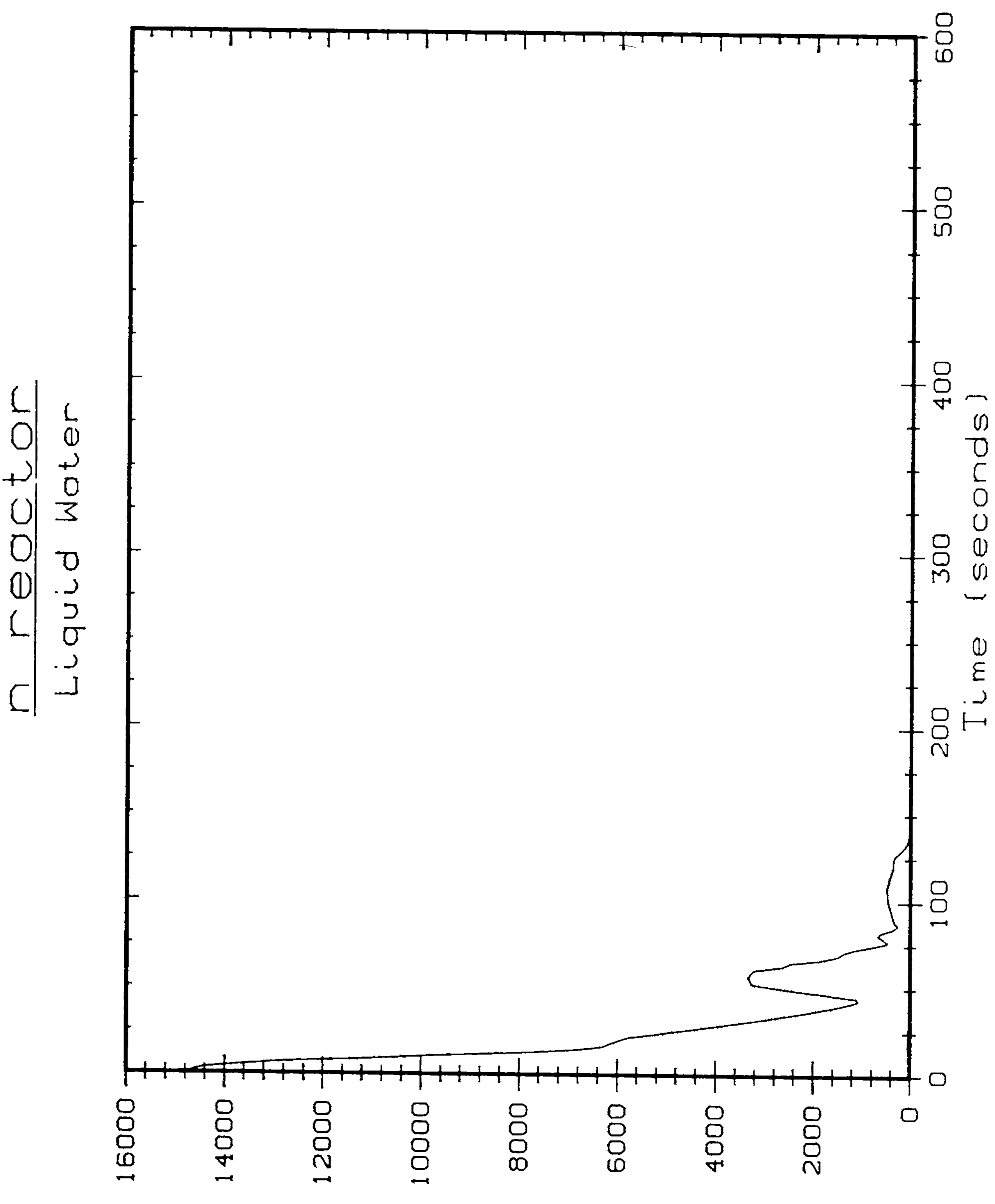


Figure 5.7. Liquid Water Injection Rate

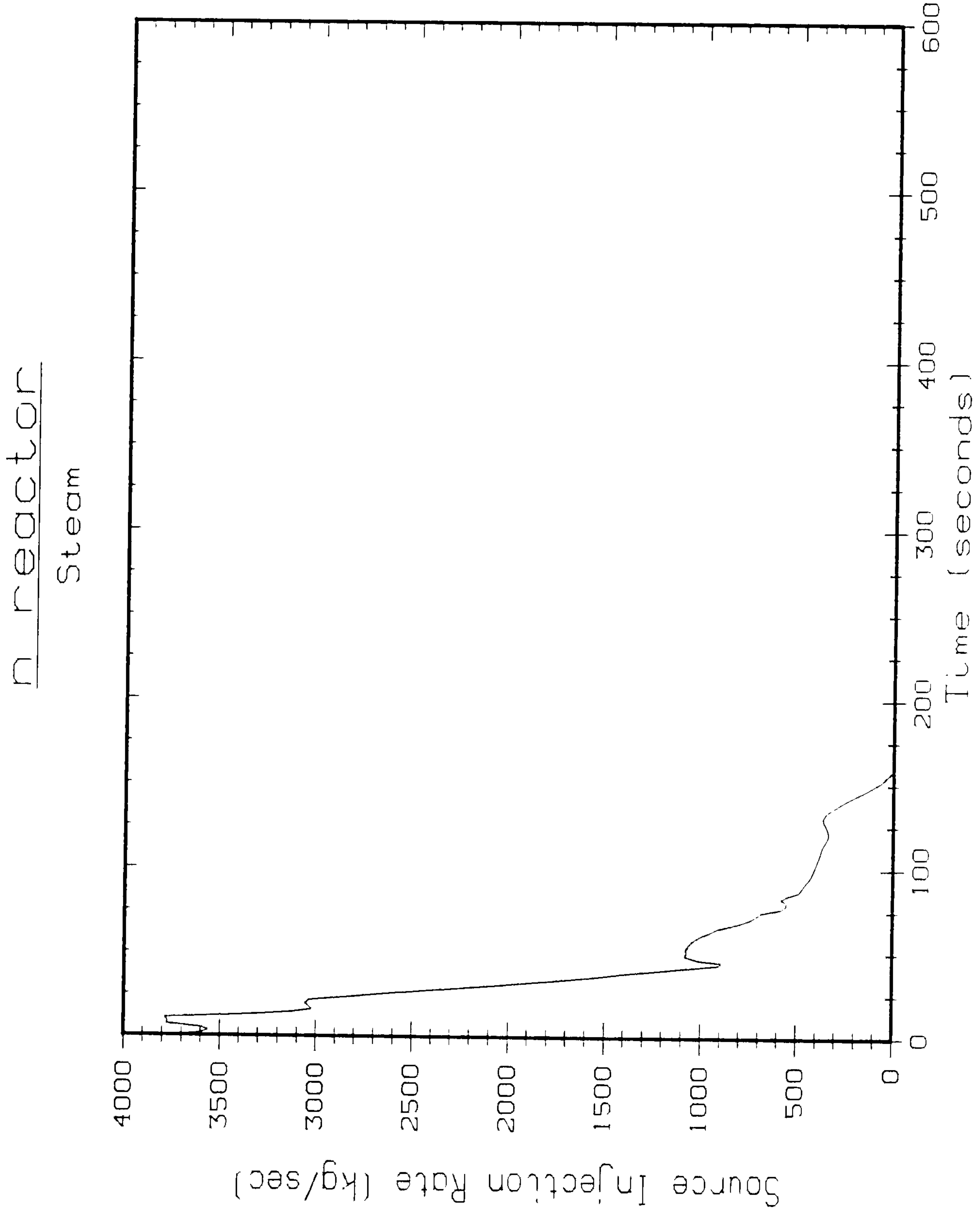


Figure 5.8. Steam Injection Rate

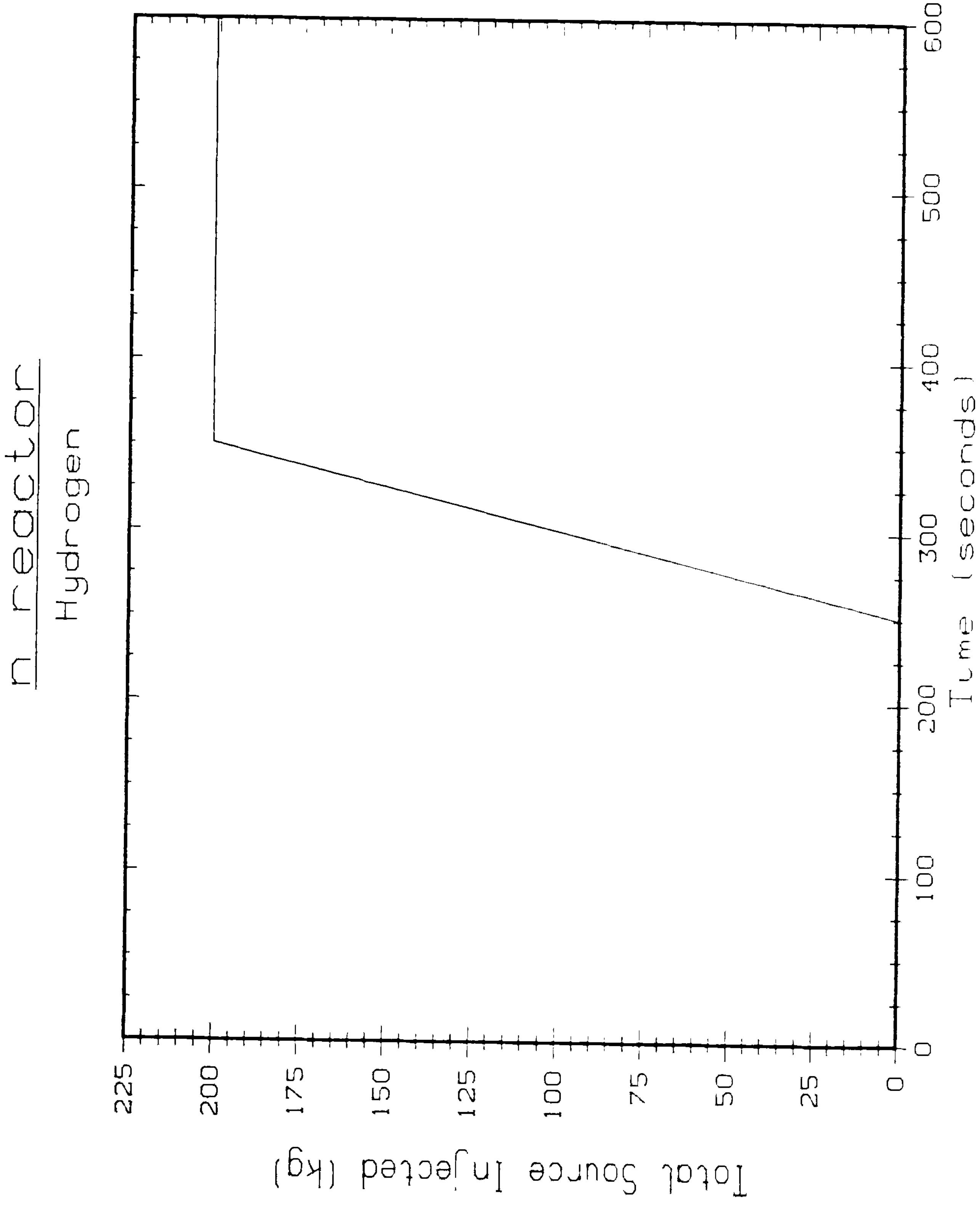


Figure 5.9. Hydrogen Source Injection

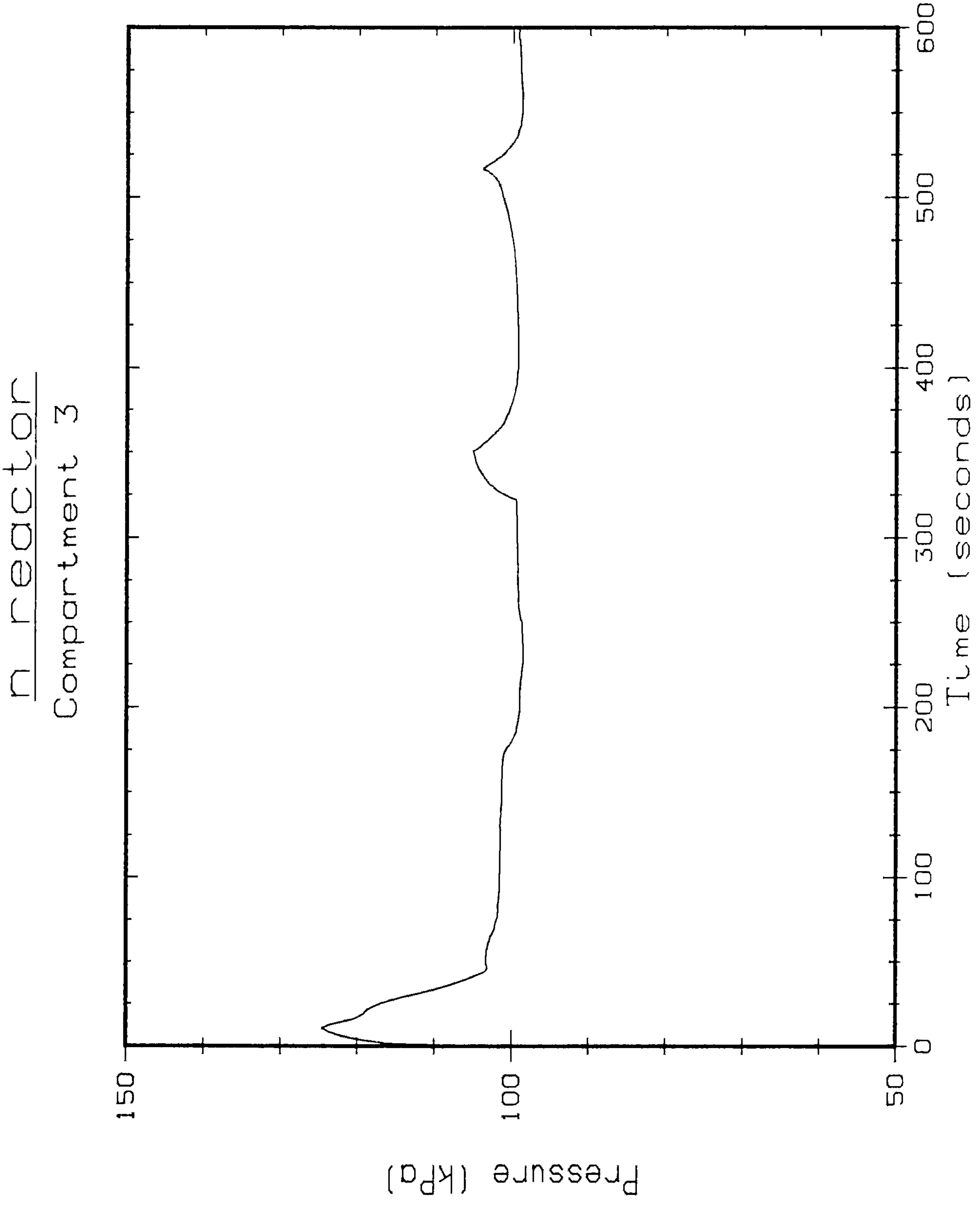


Figure 5.10. Compartment 3 Pressure Response

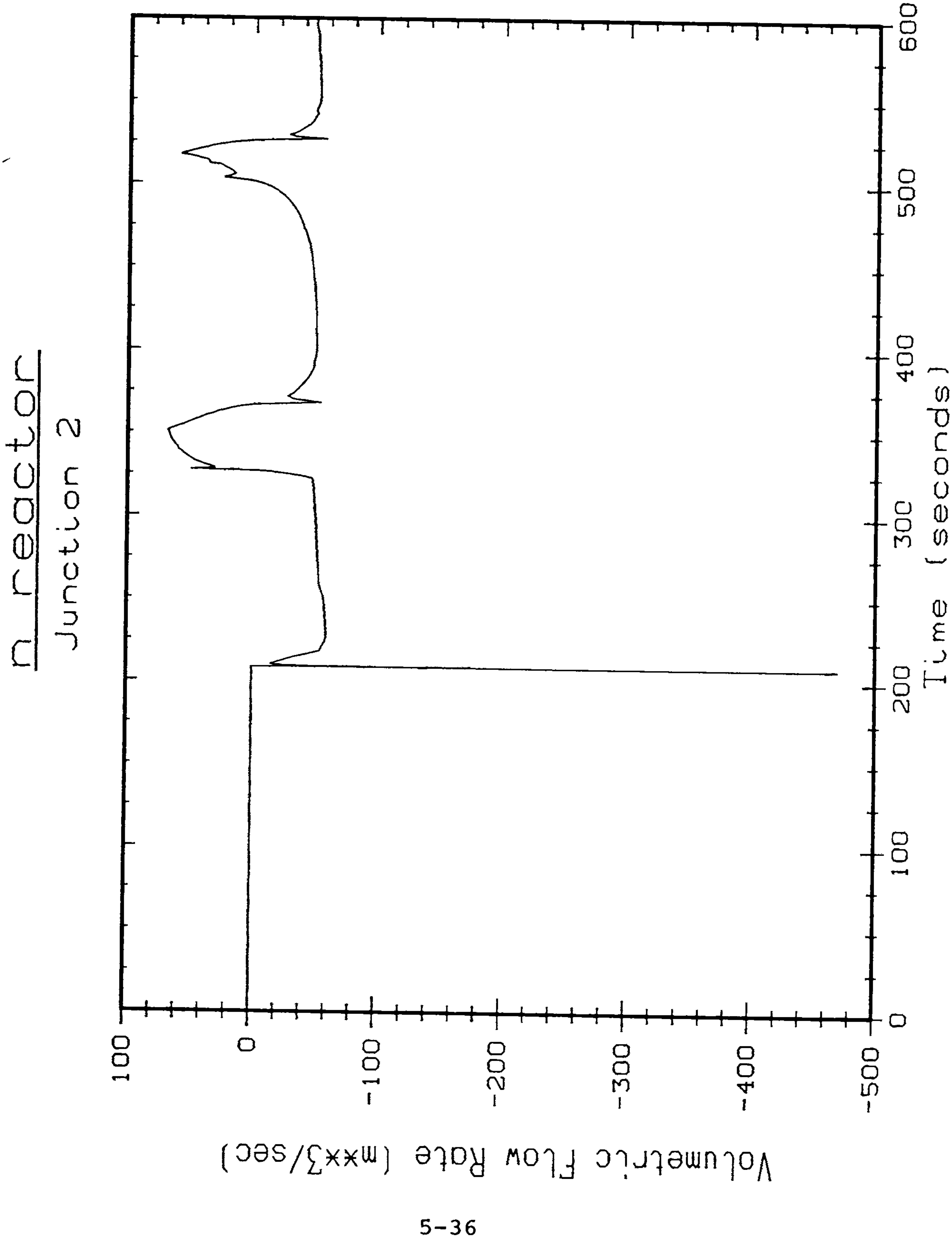


Figure 5.11. Junction 2 Volumetric Flow Rate

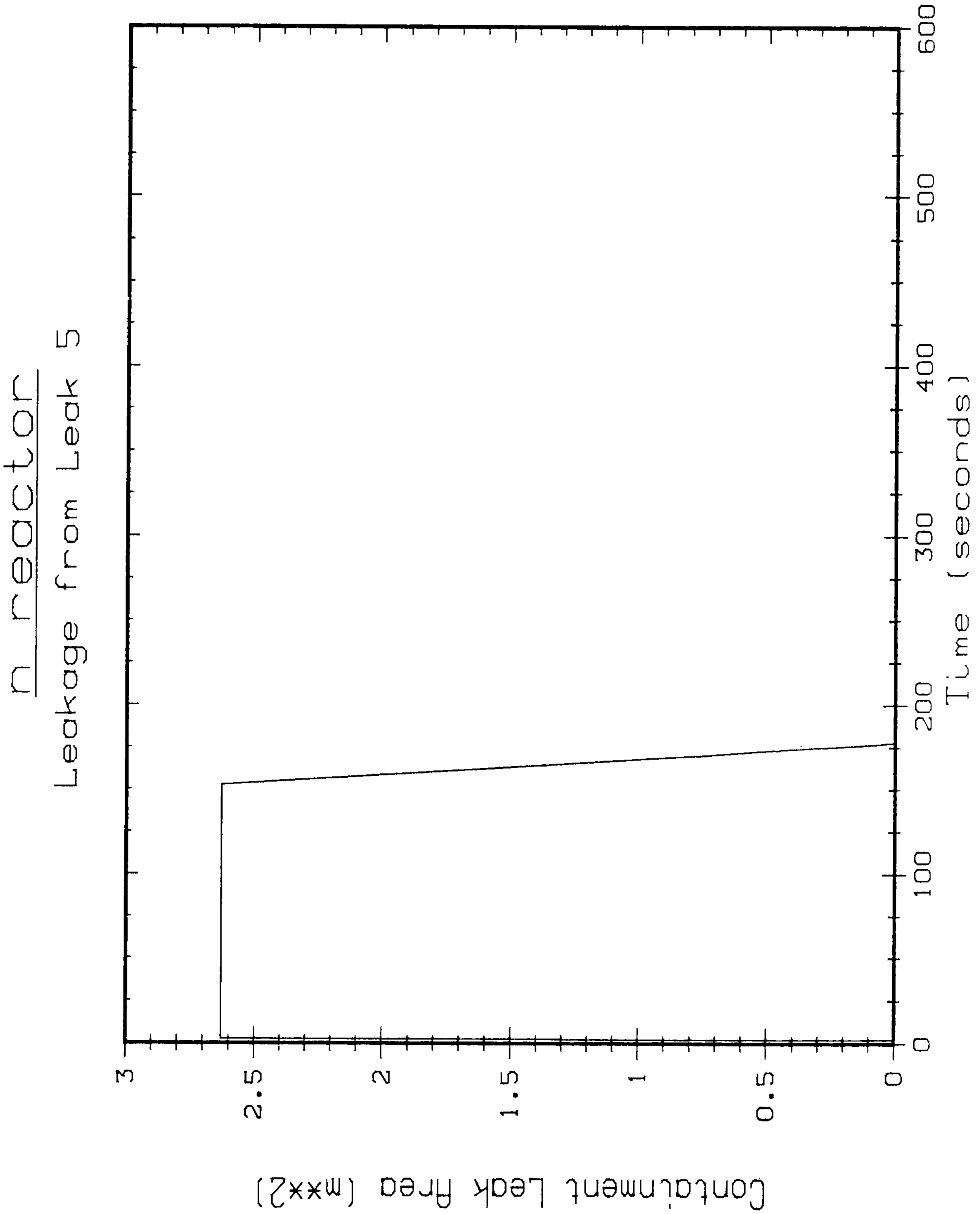


Figure 5.12. Flow Area for Steam Vent in 105 Building

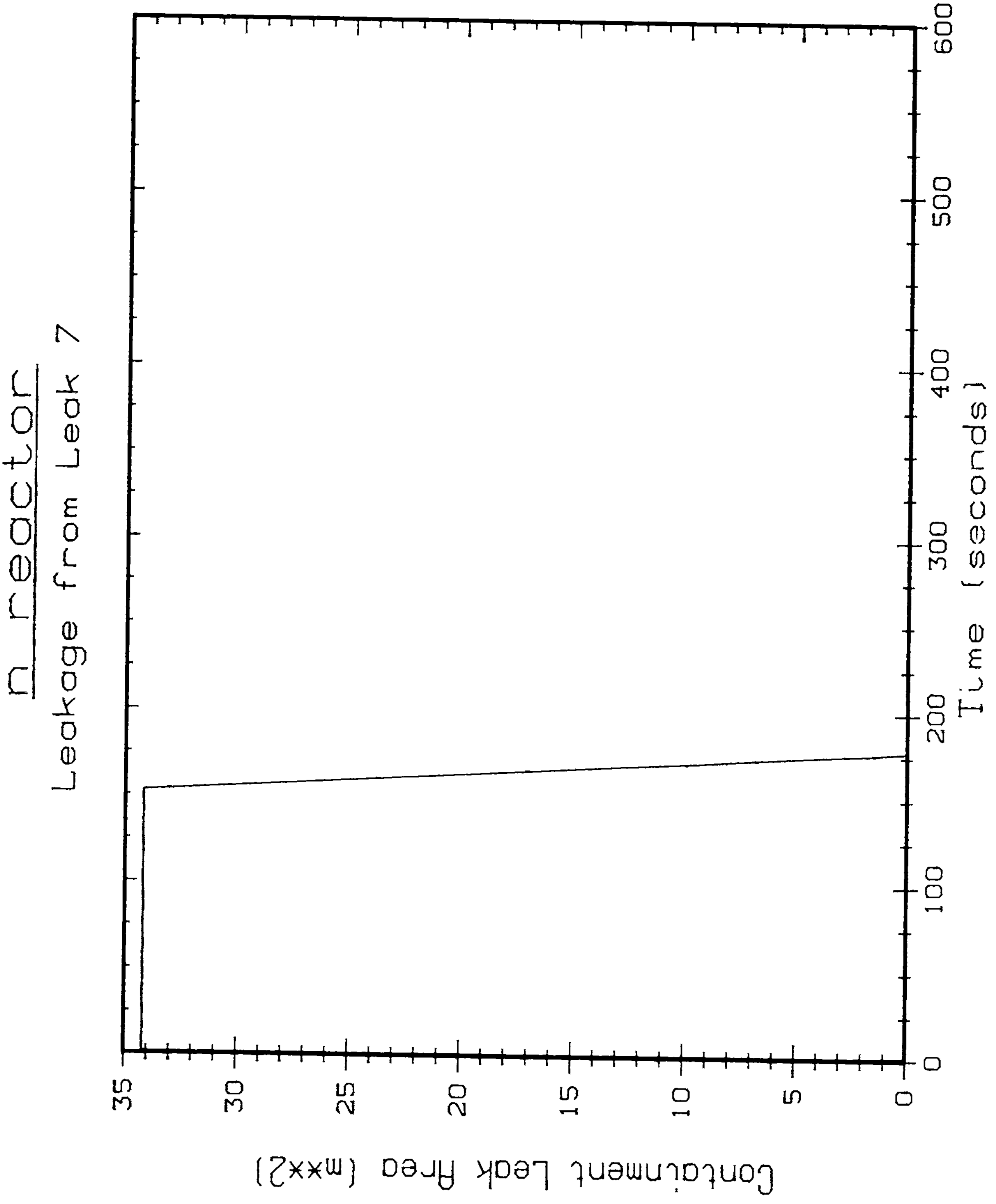


Figure 5.13. Flow Area for Steam Vents in the 109 Building

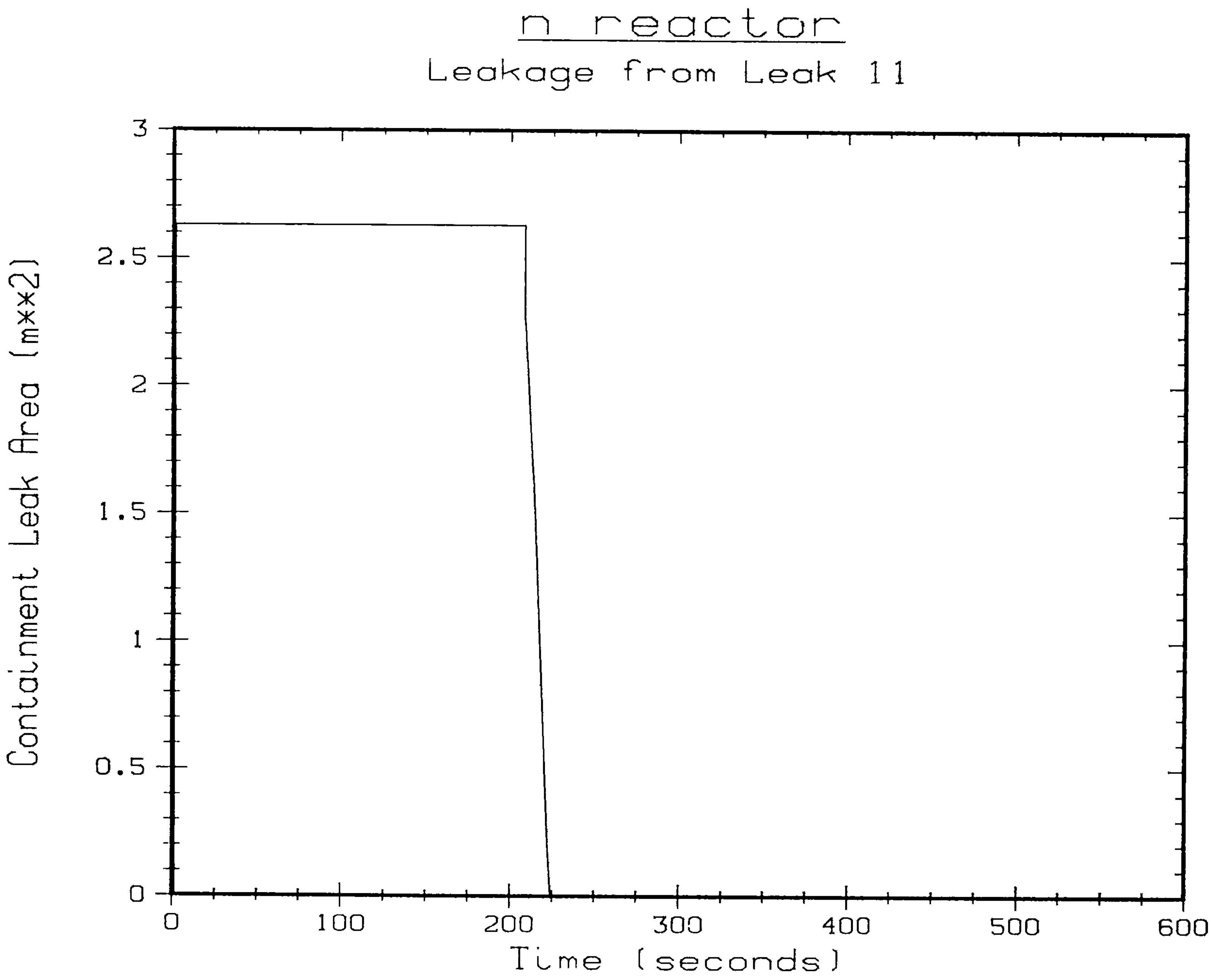


Figure 5.14. Flow Area for the Special Steam Vent in the 105 Building

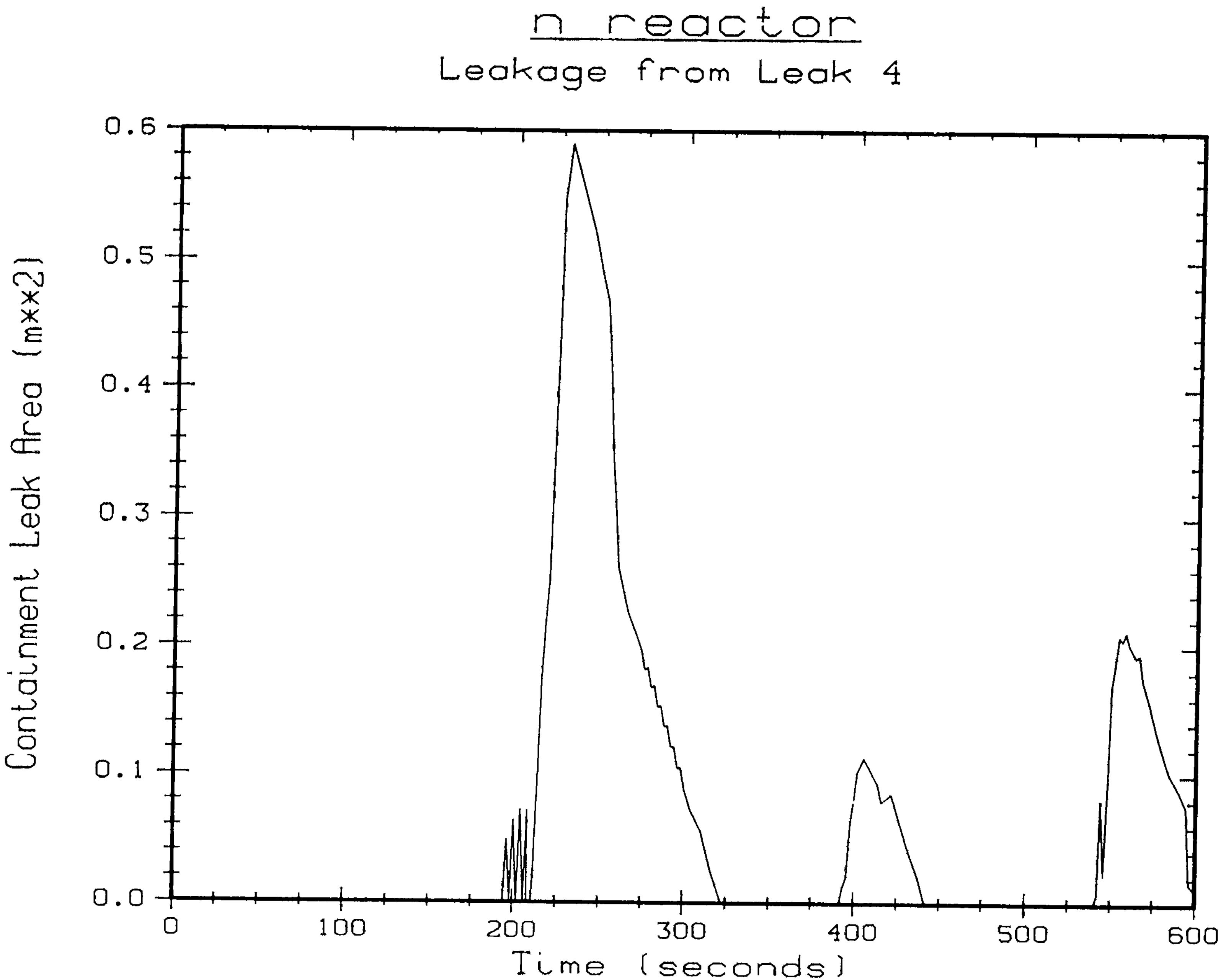


Figure 5.15. Flow Area for Vacuum Breakers in the 105 Building

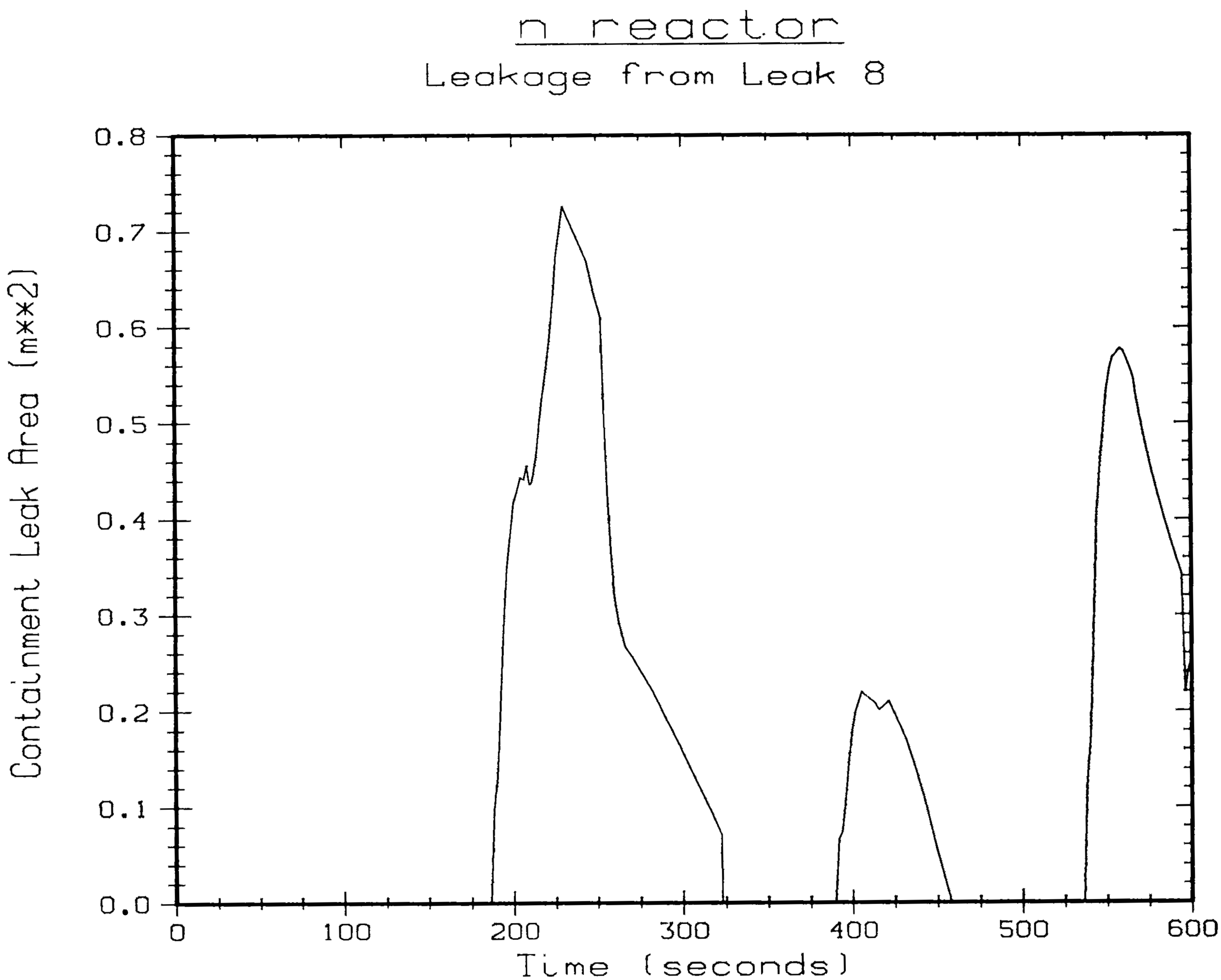


Figure 5.16. Flow Area for Vacuum Breakers in the 109 Building

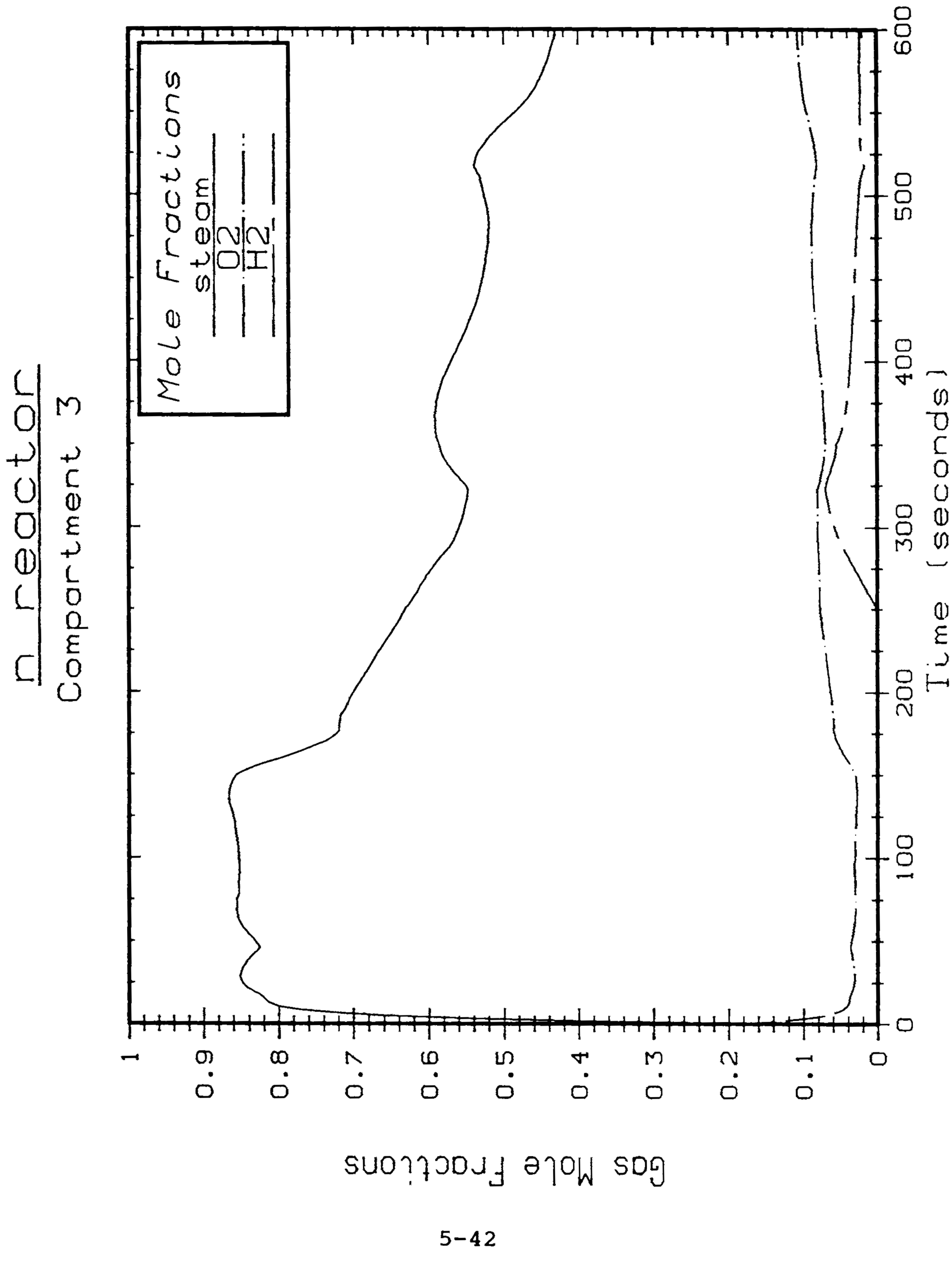


Figure 5.17. Gas Composition in Compartment 3

5.5 Output listing

A listing of the printed HECTR and ACHILES output is shown below. The initial message indicates that the confinement was not totally sealed at the beginning of the calculation due to the presence of open leakage. This message is followed by the initial conditions. Messages are then printed indicating spray actuation and progression of the hydrogen burn. After the message indicating the end of the HECTR run, summary information is presented dealing with pressures, temperatures, and mass balances. Time step information is provided indicating code performance, followed by a listing of the final compartment conditions at the end of the calculation.

ACHILES information is then printed which describes the calculation and model being used. This is followed by the table requested in the ACHILES input for compartment 3 (see Section 5.3.2).

```
KK    KK       AAA      BBBBBB   0000000  0000000  MMMM          MMMM  !!
KK  KK       AA AA     BB   BB   00   00  00   00  MM MM        MM MM  !!
KKKK        AA   AA    BB   BB   00   00  00   00  MM  MM      MM  MM  !!
KKK        AAAAAAAAA   BBBBBB    00   00  00   00  MM   MM    MM   MM  !!
KKKK       AA     AA   BB   BB   00   00  00   00  MM    MM  MM    MM  !!
KK  KK     AA     AA   BB   BB   00   00  00   00  MM     MM MM    MM
KK    KK   AA     AA   BBBBBB    0000000  0000000  MM      MMM      MM  !!
```

****
*** CONTAINMENT FAILURE CRITERION EXCEEDED AT TIME =   0.000
IN COMPARTMENT   5

INITIAL COMPARTMENT CONDITIONS AT   0.000 SECONDS ARE:

COMP #	TEMP	PRESSURE	XH2O	XN2	XO2	XH2
1	339.0	101.3	0.2030	0.6296	0.1674	0.0000
2	339.0	101.3	0.2030	0.6296	0.1674	0.0000
3	322.0	101.3	0.0925	0.7169	0.1906	0.0000
4	322.0	101.3	0.0925	0.7169	0.1906	0.0000
5	322.0	101.3	0.0925	0.7169	0.1906	0.0000

INITIAL SURFACE TEMPERATURES (K) ARE:

1.	339.0	2.	339.0	3.	477.0	4.	339.0	5.	339.0
6.	339.0	7.	505.0	8.	339.0	9.	322.0	10.	322.0
11.	322.0	12.	322.0	13.	322.0	14.	322.0	15.	322.0
16.	322.0								

SPRAY TRAIN 2 WILL BE ACTIVATED AT   44.395 SECONDS
BASED ON CRITERIA 1 IN COMPARTMENTS:
3 4

SPRAY TRAIN 1 WILL BE ACTIVATED AT   44.706 SECONDS
BASED ON CRITERIA 1 IN COMPARTMENTS:
1

BURN INITIATED IN COMPARTMENT 3 AT TIME =   322.130 SECONDS

COMPARTMENT CONDITIONS AT   322.130 SECONDS ARE:

COMP #	TEMP	PRESSURE	XH2O	XN2	XO2	XH2
1	309.5	99.5	0.0583	0.7439	0.1978	0.0000
2	322.3	99.5	0.1143	0.6997	0.1860	0.0000
3	362.7	99.4	0.5472	0.3023	0.0804	0.0702
4	361.2	99.4	0.6399	0.2729	0.0725	0.0146
5	316.7	101.2	0.0863	0.7218	0.1919	0.0000

BURN COMPLETED IN COMPARTMENT 3 AT TIME =   516.970 SECONDS

COMPARTMENT CONDITIONS AT   516.970 SECONDS ARE:

COMP #	TEMP	PRESSURE	XH2O	XN2	XO2	XH2
1	303.1	103.7	0.0317	0.7638	0.2029	0.0017
2	316.8	103.7	0.0735	0.7243	0.1909	0.0113
3	495.0	104.3	0.5398	0.3629	0.0807	0.0166

```
4      408.2      104.3     0.5297     0.3535     0.0857     0.0311
5      316.0      101.2     0.0764     0.7295     0.1939     0.0002

##############################################################################
############################### END OF HECTR RUN ##############################
##############################################################################

SUMMARY OF BURNS:

     1 BURN(S) OCCURRED IN COMPARTMENT   3

>>> GLOBAL PRESSURE AND TEMPERATURE MAXIMUMS <<<

>>>    10.632 SECONDS              124.6 KPA <<<
>>>   516.970 SECONDS              495.0 K   <<<

COMPARTMENT PRESSURE MAXIMUMS (KPA):

     1.  122.2       2.  122.9       3.  124.6       4.  124.6       5.  101.3

COMPARTMENT TEMPERATURE MAXIMUMS (K):

     1.  361.0       2.  368.1       3.  495.0       4.  409.3       5.  322.0

SURFACE TEMPERATURE MAXIMUMS (K):

     1.  352.5       2.  348.8       3.  477.0       4.  341.6       5.  341.9
     6.  357.1       7.  505.0       8.  345.6       9.  366.2      10.  360.2
    11.  347.8      12.  366.2      13.  353.3      14.  344.7      15.  322.0
    16.  322.0
```

TOTAL MASSES	WATER+ICE	STEAM	NITROGEN	OXYGEN	HYDROGEN
INITIAL	5.060E+05	7.443E+03	6.803E+04	2.066E+04	0.000E+00
INJECTED SOURCE	3.720E+05	1.726E+05	0.000E+00	0.000E+00	2.009E+02
INJECTED SPRAY	3.412E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
FINAL	9.537E+05	1.820E+04	4.581E+04	1.324E+04	1.166E+02
LEAKED	0.000E+00	1.188E+05	2.222E+04	6.747E+03	4.228E-01

```
FINAL SUMP VOLUMES (M**3):

    1.    16.900
    2.   413.559
    3.   530.332

NUMBER OF TIME STEPS TAKEN:
   HEAT TRANSFER   =      322
```

```
FLOW            =      690
SUCCESSFUL FLOW =      574


NUMBER OF FLOW TIME STEPS REPEATED AND REASON:
         70    FLOW REVERSAL
         28    CHOKING
         16    EXCESSIVE PRESSURE CHANGE
          0    TOTAL FLOW LEAVING COMPARTMENT TOO LARGE
          0    NEGATIVE MOLES
          1    TEMPERATURE OFF TABLES
          0    TEMPERATURE TOO LOW
          0    EXCESSIVE PRESSURE OR TEMPERATURE CHANGE FOR HEAT TRANSFER


NUMBER OF REJECTED TIME STEPS =        1


FLOW TIME STEP CONTROLLING FACTORS AND TIMES USED:
        309    PRESSURE CHANGE
          0    TOTAL FLOW LEAVING COMPARTMENT TOO LARGE
         28    MAXIMUM STRETCH FACTOR
          0    MINIMUM STEP SIZE
        237    MAXIMUM STEP SIZE
          0    MATCHING HEAT TRANSFER UPDATING TIME
```

FINAL COMPARTMENT CONDITIONS AT   600.221 SECONDS ARE:

COMP #	TEMP	PRESSURE	XH2O	XN2	XO2	XH2
1	300.9	99.5	0.0336	0.7625	0.2026	0.0014
2	303.7	99.5	0.0433	0.7500	0.1981	0.0087
3	376.8	99.2	0.4293	0.4396	0.1074	0.0237
4	386.2	99.2	0.4845	0.3939	0.0948	0.0268
5	314.6	101.2	0.0809	0.7260	0.1930	0.0001

```
1$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
 $ HECTR VERSION 1.5                                                              $
 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

    N REACTOR$
```

THIS IS A 5 VOLUME N REACTOR DECK FOR EXAMPLE PURPOSES.
THIS CALCULATION DOES NOT REPRESENT ANY PARTICULAR SCENARIO.

ALL SI UNITS

>>>   5 COMPARTMENT(S)   7 FLOW JUNCTION(S)   16 SURFACE(S) <<<

```
>>>   0 FAN(S)                 3 SUMP(S)                 4 GASES      <<<

    SPRAY TRAIN  1 WAS AUTO

    SPRAY TRAIN  2 WAS AUTO

    FANS WERE OFF

    FAN COOLER WAS OFF


MINIMUM HEAT TRANSFER TIMESTEP      = 1.000E-05 SECONDS
MAXIMUM HEAT TRANSFER TIMESTEP      = 2.000E+00 SECONDS
MINIMUM FLOW TIMESTEP               = 1.000E-06 SECONDS
MAXIMUM FLOW TIMESTEP               = 2.000E+00 SECONDS
MAXIMUM TIMESTEP PRESSURE CHANGE    = 10.1325   KPA
MAXIMUM TIMESTEP TEMPERATURE CHANGE = 10.0000   K


HYDROGEN LIMITS FOR    IGNITION   PROPAGATION   PROPAGATION   PRCPAGATION
                                    UPWARDS       SIDEWAYS     DOWNWARDS

COMPARTMENT   1           7.0%        4.1%          6.0%          9.0%
COMPARTMENT   2           7.0%        4.1%          6.0%          9.0%
COMPARTMENT   3           7.0%        4.1%          6.0%          9.0%
COMPARTMENT   4           7.0%        4.1%          6.0%          9.0%
COMPARTMENT   5           7.0%        4.1%          6.0%          9.0%
-------------------------------------------------------------------------------

COMPARTMENTS:

  1. C1-FRONTRXBLD
  2. C2-REARRXBLD
  3. C3-PIPE-GALL
  4. C4-6SG-AUXCELLS
  5. C5-FILTERBLD
-------------------------------------------------------------------------------

SURFACE TYPE KEY:
   1. SLAB
   2. LUMPED MASS
   3. POOL
   4. ICE
   5. ICE CONDENSER WALL


SURFACES (BY COMPARTMENT NUMBER - SURFACE TYPE -
          NUMBER OF LAYERS IF A SLAB) FOLLOWED BY THE SURFACE NUMBER
         (AND THE SUMP NUMBER IF A SUMP):

(  1-3)     1. ( 1) SUMP1
(  1-1-1)   2.      CONC1
(  1-1-1)   3.      CONC1H
(  1-2)     4.      STEEL1
(  2-3)     5. ( 2) SUMP2
(  2-1-1)   6.      CONC2
(  2-1-1)   7.      CONC2H
(  2-2)     8.      STEEL2
```

```
( 3-3)     9. ( 3) SUMP3
( 3-1-1)  10.      CONC3
( 3-2)    11.      STEEL3
( 4-3)    12. ( 3) SUMP4
( 4-1-1)  13.      CONC4
( 4-2)    14.      STEEL4
( 5-1-1)  15.      CONC5
( 5-2)    16.      STEEL5
```

```
FLOW JUNCTIONS/COMPARTMENT INTERCONNECTIONS (INTERCONNECTION AREA IN M**2 -
                                             FLOW COEFFICIENT):

  1.   1 => 2   2-WAY              SIDEWAYS   (   24.20 -   1.40)
  2.   1 => 5   TRIP VALVE         SIDEWAYS   (    0.00 -  66.26)
  3.   3 => 4   2-WAY              SIDEWAYS   (  333.60 -   1.00)
  4.   3 => 4   2-WAY              SIDEWAYS   (    3.25 -   2.00)
  5.   3 => 2   2-WAY              UPWARDS    (    2.37 -   2.00)
  6.   3 => 2   TRIP VALVE         UPWARDS    (    0.00 -   2.00)
  7.   3 => 4   FLOODED JUNCTION   SIDEWAYS   (  243.24 -   2.00)
```

```
COMPARTMENTS WITH CONTAINMENT LEAKS -
     1    1    1    1    2    3    3    3    4    4    5
```

```
*** THIS RUN ENDED AT   600.221 SECONDS ***
```

APPROXIMATE GLOBAL PRESSURE AND TEMPERATURE MAXIMUMS

```
  10.632 SECONDS          124.6 KPA
 516.459 SECONDS          487.9 K
```

APPROXIMATE COMPARTMENT PRESSURE AND TEMPERATURE MAXIMUMS

```
COMPARTMENT   1:        10.632 SECONDS      122.1 KPA
                        62.585 SECONDS      361.0 K

COMPARTMENT   2:        10.632 SECONDS      122.9 KPA
                        58.585 SECONDS      368.1 K

COMPARTMENT   3:        10.632 SECONDS      124.6 KPA
                       516.459 SECONDS      487.9 K

COMPARTMENT   4:        10.632 SECONDS      124.6 KPA
                       523.080 SECONDS      409.3 K

COMPARTMENT   5:         0.000 SECONDS      101.3 KPA
                         0.000 SECONDS      322.0 K
```

UOF = 8 UOA = 9

NHT = 323 NFL = 460 NAH = 323

1COMPARTMENT 3

TIME (SECONDS)	PRESSURE (KPA)	TEMP (K)	XH2O	XN2	XO2	XH2	BURN?	DENSITY (KG/M**3)	H2 RATE (KG/SEC)	H2O RATE (KG/SEC)	QUALITY
0.000	101.3	322.0	0.0925	0.7169	0.1906	0.0000	F	1.054	0.000E+00	0.000E+00	0.000
0.395	105.2	329.7	0.1611	0.6627	0.1762	0.0000	F	1.041	0.000E+00	1.824E+04	0.202
0.706	108.8	337.6	0.2227	0.6140	0.1632	0.0000	F	1.026	0.000E+00	1.843E+04	0.200
1.061	112.6	345.4	0.2860	0.5640	0.1499	0.0000	F	1.012	0.000E+00	1.829E+04	0.199
1.752	116.2	353.1	0.3904	0.4816	0.1280	0.0000	F	0.978	0.000E+00	1.822E+04	0.197
3.080	118.9	360.9	0.5342	0.3680	0.0978	0.0000	F	0.919	0.000E+00	1.797E+04	0.198
4.884	121.0	366.4	0.6535	0.2738	0.0728	0.0000	F	0.872	0.000E+00	1.731E+04	0.208
6.766	122.7	369.6	0.7278	0.2150	0.0572	0.0000	F	0.846	0.000E+00	1.652E+04	0.229
8.709	123.8	371.3	0.7727	0.1795	0.0477	0.0000	F	0.831	0.000E+00	1.484E+04	0.254
10.632	124.6	372.3	0.8011	0.1571	0.0418	0.0000	F	0.822	0.000E+00	1.359E+04	0.278
12.468	123.7	372.1	0.8119	0.1486	0.0395	0.0000	F	0.812	0.000E+00	1.119E+04	0.300
14.392	122.1	372.4	0.8171	0.1445	0.0384	0.0000	F	0.798	0.000E+00	9.951E+03	0.314
16.124	120.6	372.7	0.8204	0.1419	0.0377	0.0000	F	0.786	0.000E+00	9.333E+03	0.324
17.903	119.6	373.0	0.8265	0.1371	0.0364	0.0000	F	0.777	0.000E+00	9.183E+03	0.331
19.582	119.1	373.1	0.8334	0.1316	0.0350	0.0000	F	0.770	0.000E+00	9.049E+03	0.338
21.422	118.7	373.2	0.8411	0.1255	0.0334	0.0000	F	0.765	0.000E+00	8.832E+03	0.344
23.155	118.0	372.9	0.8455	0.1221	0.0324	0.0000	F	0.759	0.000E+00	8.140E+03	0.351
24.903	117.0	372.5	0.8487	0.1195	0.0318	0.0000	F	0.752	0.000E+00	7.568E+03	0.357
26.641	115.8	372.1	0.8507	0.1180	0.0314	0.0000	F	0.745	0.000E+00	6.931E+03	0.362
28.590	114.2	371.7	0.8514	0.1174	0.0312	0.0000	F	0.735	0.000E+00	6.206E+03	0.368
30.583	112.4	371.4	0.8506	0.1180	0.0314	0.0000	F	0.724	0.000E+00	5.487E+03	0.374
32.381	110.9	371.2	0.8493	0.1190	0.0316	0.0000	F	0.715	0.000E+00	4.914E+03	0.384
34.351	109.3	370.8	0.8471	0.1208	0.0321	0.0000	F	0.706	0.000E+00	4.284E+03	0.394
36.119	108.0	370.4	0.8445	0.1228	0.0327	0.0000	F	0.699	0.000E+00	3.762E+03	0.408
37.829	106.9	370.0	0.8422	0.1247	0.0331	0.0000	F	0.693	0.000E+00	3.311E+03	0.426
39.710	105.8	369.6	0.8393	0.1270	0.0338	0.0000	F	0.688	0.000E+00	2.807E+03	0.446
41.665	104.7	369.2	0.8351	0.1303	0.0346	0.0000	F	0.683	0.000E+00	2.337E+03	0.456
43.317	103.8	368.7	0.8303	0.1340	0.0356	0.0000	F	0.680	0.000E+00	1.969E+03	0.460
44.719	103.3	368.6	0.8266	0.1370	0.0364	0.0000	F	0.678	0.000E+00	2.020E+03	0.441
46.250	103.1	368.8	0.8260	0.1374	0.0365	0.0000	F	0.677	0.000E+00	2.585E+03	0.390
47.184	103.2	369.1	0.8270	0.1366	0.0363	0.0000	F	0.676	0.000E+00	2.871E+03	0.365
48.585	103.3	369.4	0.8294	0.1348	0.0358	0.0000	F	0.675	0.000E+00	3.300E+03	0.327
50.585	103.3	369.8	0.8330	0.1320	0.0351	0.0000	F	0.673	0.000E+00	3.913E+03	0.275
52.585	103.3	370.0	0.8369	0.1288	0.0342	0.0000	F	0.672	0.000E+00	4.334E+03	0.248
54.585	103.2	370.1	0.8409	0.1257	0.0334	0.0000	F	0.670	0.000E+00	4.359E+03	0.245
56.585	103.2	370.1	0.8448	0.1226	0.0326	0.0000	F	0.668	0.000E+00	4.383E+03	0.241
58.585	103.1	370.1	0.8482	0.1199	0.0319	0.0000	F	0.666	0.000E+00	4.314E+03	0.239
60.585	103.0	370.0	0.8512	0.1176	0.0313	0.0000	F	0.665	0.000E+00	4.221E+03	0.237
62.585	102.8	369.9	0.8534	0.1158	0.0308	0.0000	F	0.663	0.000E+00	3.587E+03	0.266
64.585	102.7	369.8	0.8553	0.1143	0.0304	0.0000	F	0.662	0.000E+00	3.390E+03	0.271
66.585	102.5	369.6	0.8559	0.1138	0.0303	0.0000	F	0.661	0.000E+00	2.669E+03	0.317
68.585	102.3	369.4	0.8560	0.1138	0.0302	0.0000	F	0.660	0.000E+00	2.289E+03	0.342
70.585	102.2	369.2	0.8558	0.1139	0.0303	0.0000	F	0.659	0.000E+00	2.118E+03	0.348
72.585	102.1	369.2	0.8558	0.1139	0.0303	0.0000	F	0.659	0.000E+00	1.878E+03	0.378
74.585	102.0	369.1	0.8560	0.1138	0.0302	0.0000	F	0.658	0.000E+00	1.473E+03	0.465
76.585	101.8	368.9	0.8545	0.1149	0.0305	0.0000	F	0.658	0.000E+00	1.067E+03	0.552
78.585	101.7	368.8	0.8533	0.1159	0.0308	0.0000	F	0.658	0.000E+00	1.108E+03	0.503
80.585	101.7	368.8	0.8528	0.1163	0.0309	0.0000	F	0.658	0.000E+00	1.227E+03	0.450
82.585	101.7	368.9	0.8536	0.1157	0.0308	0.0000	F	0.658	0.000E+00	1.173E+03	0.496
84.585	101.7	368.9	0.8538	0.1155	0.0307	0.0000	F	0.657	0.000E+00	9.211E+02	0.593
86.585	101.6	368.8	0.8532	0.1160	0.0308	0.0000	F	0.657	0.000E+00	7.591E+02	0.646

88.585	101.6	368.8	0.8529	0.1162	0.0309	0.0000	F	0.657	0.000E+00	8.141E+02	0.590
90.585	101.6	368.9	0.8527	0.1163	0.0309	0.0000	F	0.657	0.000E+00	8.332E+02	0.559
92.585	101.6	368.9	0.8526	0.1164	0.0309	0.0000	F	0.657	0.000E+00	8.409E+02	0.537
94.585	101.6	368.9	0.8526	0.1165	0.0310	0.0000	F	0.657	0.000E+00	8.440E+02	0.517
96.585	101.5	368.9	0.8526	0.1164	0.0309	0.0000	F	0.657	0.000E+00	8.537E+02	0.500
98.585	101.5	368.9	0.8528	0.1163	0.0309	0.0000	F	0.657	0.000E+00	8.652E+02	0.483
100.585	101.5	368.9	0.8531	0.1160	0.0308	0.0000	F	0.656	0.000E+00	8.767E+02	0.466
102.585	101.5	369.0	0.8535	0.1157	0.0308	0.0000	F	0.656	0.000E+00	8.785E+02	0.458
104.585	101.5	369.0	0.8540	0.1154	0.0307	0.0000	F	0.656	0.000E+00	8.779E+02	0.451
106.585	101.5	369.0	0.8545	0.1149	0.0306	0.0000	F	0.656	0.000E+00	8.772E+02	0.444
108.585	101.5	369.1	0.8551	0.1145	0.0304	0.0000	F	0.655	0.000E+00	8.701E+02	0.440
110.585	101.5	369.1	0.8557	0.1140	0.0303	0.0000	F	0.655	0.000E+00	8.473E+02	0.445
112.585	101.5	369.1	0.8564	0.1135	0.0302	0.0000	F	0.655	0.000E+00	8.245E+02	0.450
114.585	101.5	369.2	0.8570	0.1130	0.0300	0.0000	F	0.654	0.000E+00	7.979E+02	0.456
116.585	101.5	369.2	0.8576	0.1125	0.0299	0.0000	F	0.654	0.000E+00	7.626E+02	0.465
118.585	101.4	369.2	0.8580	0.1121	0.0298	0.0000	F	0.654	0.000E+00	7.272E+02	0.473
120.585	101.4	369.2	0.8585	0.1118	0.0297	0.0000	F	0.653	0.000E+00	7.019E+02	0.481
122.585	101.4	369.2	0.8592	0.1112	0.0296	0.0000	F	0.653	0.000E+00	7.010E+02	0.487
124.585	101.4	369.3	0.8601	0.1105	0.0294	0.0000	F	0.653	0.000E+00	7.001E+02	0.493
126.585	101.4	369.3	0.8613	0.1096	0.0291	0.0000	F	0.652	0.000E+00	6.796E+02	0.520
128.585	101.5	369.4	0.8627	0.1085	0.0288	0.0000	F	0.652	0.000E+00	6.120E+02	0.596
130.585	101.5	369.4	0.8642	0.1073	0.0285	0.0000	F	0.651	0.000E+00	5.443E+02	0.673
132.585	101.4	369.5	0.8654	0.1063	0.0283	0.0000	F	0.651	0.000E+00	4.766E+02	0.750
134.585	101.4	369.4	0.8663	0.1057	0.0281	0.0000	F	0.650	0.000E+00	4.089E+02	0.827
136.585	101.4	369.4	0.8666	0.1054	0.0280	0.0000	F	0.650	0.000E+00	3.496E+02	0.887
138.585	101.4	369.4	0.8664	0.1055	0.0281	0.0000	F	0.650	0.000E+00	3.105E+02	0.907
140.585	101.3	369.3	0.8658	0.1060	0.0282	0.0000	F	0.650	0.000E+00	2.714E+02	0.926
142.585	101.3	369.2	0.8647	0.1069	0.0284	0.0000	F	0.650	0.000E+00	2.324E+02	0.946
144.585	101.3	369.2	0.8631	0.1081	0.0287	0.0000	F	0.651	0.000E+00	1.933E+02	0.965
146.585	101.3	369.1	0.8611	0.1097	0.0292	0.0000	F	0.652	0.000E+00	1.542E+02	0.985
148.585	101.3	369.0	0.8587	0.1116	0.0297	0.0000	F	0.653	0.000E+00	1.202E+02	0.992
150.585	101.3	368.7	0.8538	0.1155	0.0307	0.0000	F	0.655	0.000E+00	8.752E+01	0.996
152.585	101.3	368.1	0.8448	0.1226	0.0326	0.0000	F	0.659	0.000E+00	5.919E+01	1.000
154.585	101.3	367.4	0.8339	0.1312	0.0349	0.0000	F	0.664	0.000E+00	4.135E+01	1.000
156.585	101.3	366.5	0.8212	0.1412	0.0375	0.0000	F	0.670	0.000E+00	2.351E+01	1.000
158.585	101.2	365.6	0.8061	0.1532	0.0407	0.0000	F	0.677	0.000E+00	0.000E+00	0.000
160.585	101.2	364.9	0.7921	0.1642	0.0437	0.0000	F	0.683	0.000E+00	0.000E+00	0.000
162.585	101.2	364.6	0.7793	0.1743	0.0463	0.0000	F	0.688	0.000E+00	0.000E+00	0.000
164.585	101.2	364.5	0.7675	0.1837	0.0488	0.0000	F	0.692	0.000E+00	0.000E+00	0.000
166.585	101.2	364.6	0.7566	0.1923	0.0511	0.0000	F	0.696	0.000E+00	0.000E+00	0.000
168.585	101.2	364.9	0.7463	0.2005	0.0533	0.0000	F	0.699	0.000E+00	0.000E+00	0.000
170.585	101.1	365.1	0.7369	0.2078	0.0552	0.0000	F	0.701	0.000E+00	0.000E+00	0.000
172.585	101.0	365.4	0.7290	0.2141	0.0569	0.0000	F	0.703	0.000E+00	0.000E+00	0.000
174.585	100.9	365.6	0.7230	0.2188	0.0582	0.0000	F	0.703	0.000E+00	0.000E+00	0.000
176.585	100.6	365.8	0.7196	0.2215	0.0589	0.0000	F	0.702	0.000E+00	0.000E+00	0.000
178.006	100.4	366.0	0.7193	0.2217	0.0589	0.0000	F	0.701	0.000E+00	0.000E+00	0.000
179.362	100.2	366.1	0.7190	0.2220	0.0590	0.0000	F	0.699	0.000E+00	0.000E+00	0.000
180.834	100.0	366.0	0.7187	0.2222	0.0591	0.0000	F	0.698	0.000E+00	0.000E+00	0.000
182.459	99.8	366.0	0.7182	0.2226	0.0592	0.0000	F	0.697	0.000E+00	0.000E+00	0.000
184.305	99.6	365.8	0.7175	0.2232	0.0593	0.0000	F	0.696	0.000E+00	0.000E+00	0.000
186.305	99.4	365.6	0.7167	0.2238	0.0595	0.0000	F	0.695	0.000E+00	0.000E+00	0.000
188.305	99.4	365.3	0.7133	0.2265	0.0602	0.0000	F	0.697	0.000E+00	0.000E+00	0.000
190.305	99.3	365.0	0.7111	0.2282	0.0607	0.0000	F	0.697	0.000E+00	0.000E+00	0.000
192.305	99.2	364.8	0.7093	0.2296	0.0610	0.0000	F	0.698	0.000E+00	0.000E+00	0.000
194.305	99.1	364.5	0.7072	0.2313	0.0615	0.0000	F	0.698	0.000E+00	0.000E+00	0.000
196.305	99.0	364.2	0.7048	0.2332	0.0620	0.0000	F	0.699	0.000E+00	0.000E+00	0.000
198.305	99.0	363.9	0.7022	0.2353	0.0625	0.0000	F	0.701	0.000E+00	0.000E+00	0.000
200.305	99.0	363.7	0.6994	0.2375	0.0631	0.0000	F	0.702	0.000E+00	0.000E+00	0.000
202.305	98.9	363.4	0.6968	0.2396	0.0637	0.0000	F	0.703	0.000E+00	0.000E+00	0.000
204.305	99.0	363.2	0.6939	0.2418	0.0643	0.0000	F	0.705	0.000E+00	0.000E+00	0.000

206.305	98.9	362.9	0.6912	0.2439	0.0648	0.0000	F	0.706	0.000E+00	0.000E+00	0.000
208.305	98.9	362.7	0.6884	0.2462	0.0654	0.0000	F	0.707	0.000E+00	0.000E+00	0.000
209.987	99.0	362.5	0.6858	0.2482	0.0660	0.0000	F	0.709	0.000E+00	0.000E+00	0.000
210.859	98.9	362.4	0.6846	0.2492	0.0662	0.0000	F	0.709	0.000E+00	0.000E+00	0.000
212.168	98.9	362.2	0.6829	0.2505	0.0666	0.0000	F	0.710	0.000E+00	0.000E+00	0.000
214.130	98.9	361.9	0.6804	0.2525	0.0671	0.0000	F	0.711	0.000E+00	0.000E+00	0.000
216.130	98.8	361.7	0.6777	0.2546	0.0677	0.0000	F	0.712	0.000E+00	0.000E+00	0.000
218.130	98.8	361.4	0.6749	0.2568	0.0683	0.0000	F	0.714	0.000E+00	0.000E+00	0.000
220.130	98.8	361.1	0.6721	0.2590	0.0688	0.0000	F	0.715	0.000E+00	0.000E+00	0.000
222.130	98.7	360.8	0.6695	0.2611	0.0694	0.0000	F	0.716	0.000E+00	0.000E+00	0.000
224.130	98.6	360.6	0.6668	0.2632	0.0700	0.0000	F	0.717	0.000E+00	0.000E+00	0.000
226.130	98.6	360.4	0.6640	0.2654	0.0706	0.0000	F	0.718	0.000E+00	0.000E+00	0.000
228.130	98.6	360.3	0.6611	0.2678	0.0712	0.0000	F	0.719	0.000E+00	0.000E+00	0.000
230.130	98.6	360.2	0.6580	0.2701	0.0718	0.0000	F	0.720	0.000E+00	0.000E+00	0.000
232.130	98.6	360.2	0.6550	0.2726	0.0725	0.0000	F	0.721	0.000E+00	0.000E+00	0.000
234.130	98.6	360.2	0.6520	0.2749	0.0731	0.0000	F	0.722	0.000E+00	0.000E+00	0.000
236.130	98.6	360.3	0.6490	0.2773	0.0737	0.0000	F	0.723	0.000E+00	0.000E+00	0.000
238.130	98.6	360.4	0.6462	0.2795	0.0743	0.0000	F	0.724	0.000E+00	0.000E+00	0.000
240.130	98.6	360.4	0.6434	0.2817	0.0749	0.0000	F	0.725	0.000E+00	0.000E+00	0.000
242.130	98.7	360.5	0.6407	0.2838	0.0754	0.0000	F	0.726	0.000E+00	0.000E+00	0.000
244.130	98.7	360.6	0.6381	0.2859	0.0760	0.0000	F	0.727	0.000E+00	0.000E+00	0.000
246.130	98.7	360.6	0.6357	0.2878	0.0765	0.0000	F	0.728	0.000E+00	0.000E+00	0.000
248.130	98.7	360.6	0.6333	0.2897	0.0770	0.0000	F	0.729	0.000E+00	0.000E+00	0.000
250.130	98.7	360.6	0.6310	0.2915	0.0775	0.0000	F	0.730	0.000E+00	0.000E+00	0.000
252.130	98.9	361.0	0.6272	0.2923	0.0777	0.0028	F	0.729	2.000E+00	0.000E+00	0.000
254.130	99.0	361.4	0.6239	0.2928	0.0778	0.0055	F	0.728	2.000E+00	0.000E+00	0.000
256.130	99.1	361.7	0.6211	0.2929	0.0779	0.0081	F	0.726	2.000E+00	0.000E+00	0.000
258.130	99.1	362.0	0.6184	0.2930	0.0779	0.0107	F	0.725	2.000E+00	0.000E+00	0.000
260.130	99.1	362.2	0.6159	0.2930	0.0779	0.0132	F	0.723	2.000E+00	0.000E+00	0.000
262.130	99.2	362.3	0.6134	0.2930	0.0779	0.0156	F	0.722	2.000E+00	0.000E+00	0.000
264.130	99.2	362.4	0.6109	0.2931	0.0779	0.0180	F	0.720	2.000E+00	0.000E+00	0.000
266.130	99.2	362.4	0.6083	0.2933	0.0780	0.0204	F	0.719	2.000E+00	0.000E+00	0.000
268.130	99.2	362.5	0.6057	0.2935	0.0780	0.0228	F	0.718	2.000E+00	0.000E+00	0.000
270.130	99.2	362.5	0.6029	0.2939	0.0781	0.0251	F	0.717	2.000E+00	0.000E+00	0.000
272.130	99.2	362.5	0.6000	0.2943	0.0782	0.0274	F	0.716	2.000E+00	0.000E+00	0.000
274.130	99.2	362.5	0.5970	0.2948	0.0784	0.0298	F	0.715	2.000E+00	0.000E+00	0.000
276.130	99.2	362.5	0.5939	0.2954	0.0785	0.0321	F	0.714	2.000E+00	0.000E+00	0.000
278.130	99.2	362.5	0.5907	0.2961	0.0787	0.0345	F	0.713	2.000E+00	0.000E+00	0.000
280.130	99.2	362.5	0.5873	0.2969	0.0789	0.0369	F	0.712	2.000E+00	0.000E+00	0.000
282.130	99.3	362.5	0.5837	0.2977	0.0791	0.0394	F	0.711	2.000E+00	0.000E+00	0.000
284.130	99.3	362.5	0.5799	0.2987	0.0794	0.0419	F	0.710	2.000E+00	0.000E+00	0.000
286.130	99.3	362.6	0.5759	0.2998	0.0797	0.0446	F	0.709	2.000E+00	0.000E+00	0.000
288.130	99.3	362.6	0.5722	0.3008	0.0800	0.0471	F	0.708	2.000E+00	0.000E+00	0.000
290.130	99.3	362.6	0.5692	0.3014	0.0801	0.0493	F	0.707	2.000E+00	0.000E+00	0.000
292.130	99.3	362.6	0.5667	0.3018	0.0802	0.0513	F	0.706	2.000E+00	0.000E+00	0.000
294.130	99.3	362.7	0.5645	0.3021	0.0803	0.0531	F	0.706	2.000E+00	0.000E+00	0.000
296.130	99.3	362.7	0.5625	0.3023	0.0804	0.0548	F	0.705	2.000E+00	0.000E+00	0.000
298.130	99.3	362.7	0.5608	0.3025	0.0804	0.0563	F	0.704	2.000E+00	0.000E+00	0.000
300.130	99.3	362.7	0.5591	0.3026	0.0804	0.0578	F	0.703	2.000E+00	0.000E+00	0.000
302.130	99.3	362.7	0.5576	0.3026	0.0804	0.0593	F	0.703	2.000E+00	0.000E+00	0.000
304.130	99.4	362.7	0.5563	0.3027	0.0805	0.0606	F	0.702	2.000E+00	0.000E+00	0.000
306.130	99.4	362.7	0.5550	0.3027	0.0805	0.0619	F	0.701	2.000E+00	0.000E+00	0.000
308.130	99.4	362.7	0.5538	0.3027	0.0805	0.0631	F	0.701	2.000E+00	0.000E+00	0.000
310.130	99.4	362.7	0.5527	0.3026	0.0804	0.0642	F	0.700	2.000E+00	0.000E+00	0.000
312.130	99.4	362.7	0.5517	0.3026	0.0804	0.0653	F	0.700	2.000E+00	0.000E+00	0.000
314.130	99.4	362.7	0.5507	0.3025	0.0804	0.0663	F	0.699	2.000E+00	0.000E+00	0.000
316.130	99.4	362.7	0.5498	0.3025	0.0804	0.0674	F	0.699	2.000E+00	0.000E+00	0.000
318.130	99.4	362.7	0.5489	0.3024	0.0804	0.0683	F	0.698	2.000E+00	0.000E+00	0.000
320.130	99.4	362.7	0.5480	0.3023	0.0804	0.0693	F	0.698	2.000E+00	0.000E+00	0.000
322.130	99.4	362.7	0.5472	0.3023	0.0804	0.0702	F	0.697	2.000E+00	0.000E+00	0.000

323.703	100.3	372.7	0.5487	0.3017	0.0796	0.0700	T	0.684	2.000E+00	0.000E+00	0.000
324.971	100.9	380.3	0.5510	0.3007	0.0789	0.0695	T	0.673	2.000E+00	0.000E+00	0.000
326.467	101.6	388.5	0.5536	0.2997	0.0781	0.0686	T	0.663	2.000E+00	0.000E+00	0.000
328.356	102.2	397.9	0.5572	0.2985	0.0771	0.0672	T	0.651	2.000E+00	0.000E+00	0.000
329.556	102.5	403.2	0.5596	0.2976	0.0765	0.0662	T	0.644	2.000E+00	0.000E+00	0.000
331.158	102.9	409.8	0.5627	0.2966	0.0758	0.0649	T	0.636	2.000E+00	0.000E+00	0.000
332.964	103.3	416.4	0.5661	0.2954	0.0750	0.0635	T	0.628	2.000E+00	0.000E+00	0.000
333.919	103.4	419.6	0.5678	0.2948	0.0746	0.0627	T	0.624	2.000E+00	0.000E+00	0.000
335.124	103.6	423.2	0.5700	0.2941	0.0741	0.0618	T	0.620	2.000E+00	0.000E+00	0.000
336.452	103.8	426.9	0.5722	0.2933	0.0736	0.0608	T	0.616	2.000E+00	0.000E+00	0.000
337.893	104.0	430.6	0.5744	0.2926	0.0731	0.0599	T	0.612	2.000E+00	0.000E+00	0.000
339.514	104.2	434.4	0.5767	0.2918	0.0726	0.0589	T	0.608	2.000E+00	0.000E+00	0.000
340.954	104.4	437.5	0.5786	0.2912	0.0721	0.0581	T	0.604	2.000E+00	0.000E+00	0.000
342.669	104.6	440.9	0.5805	0.2905	0.0717	0.0573	T	0.601	2.000E+00	0.000E+00	0.000
344.567	104.7	444.4	0.5824	0.2899	0.0712	0.0565	T	0.597	2.000E+00	0.000E+00	0.000
346.567	104.8	447.7	0.5841	0.2893	0.0707	0.0559	T	0.593	2.000E+00	0.000E+00	0.000
348.567	105.0	450.8	0.5855	0.2889	0.0703	0.0553	T	0.589	2.000E+00	0.000E+00	0.000
350.567	105.1	453.6	0.5867	0.2885	0.0699	0.0549	T	0.586	2.000E+00	0.000E+00	0.000
352.492	104.4	447.8	0.5881	0.2890	0.0702	0.0527	T	0.591	0.000E+00	0.000E+00	0.000
354.380	103.9	443.2	0.5891	0.2895	0.0705	0.0509	T	0.596	0.000E+00	0.000E+00	0.000
355.849	103.5	440.1	0.5898	0.2899	0.0707	0.0497	T	0.599	0.000E+00	0.000E+00	0.000
357.589	103.1	436.9	0.5904	0.2903	0.0709	0.0484	T	0.601	0.000E+00	0.000E+00	0.000
359.423	102.6	434.0	0.5909	0.2908	0.0711	0.0472	T	0.604	0.000E+00	0.000E+00	0.000
361.340	102.2	431.3	0.5912	0.2913	0.0713	0.0461	T	0.606	0.000E+00	0.000E+00	0.000
362.330	102.0	430.0	0.5914	0.2916	0.0714	0.0456	T	0.606	0.000E+00	0.000E+00	0.000
363.363	101.8	428.8	0.5915	0.2919	0.0715	0.0451	T	0.607	0.000E+00	0.000E+00	0.000
364.438	101.6	427.6	0.5916	0.2922	0.0716	0.0446	T	0.608	0.000E+00	0.000E+00	0.000
365.565	101.3	426.4	0.5917	0.2925	0.0717	0.0441	T	0.609	0.000E+00	0.000E+00	0.000
366.768	101.1	425.3	0.5917	0.2928	0.0718	0.0437	T	0.609	0.000E+00	0.000E+00	0.000
368.110	101.0	424.2	0.5913	0.2935	0.0720	0.0431	T	0.611	0.000E+00	0.000E+00	0.000
370.110	100.8	422.6	0.5906	0.2947	0.0724	0.0424	T	0.613	0.000E+00	0.000E+00	0.000
371.744	100.7	421.8	0.5902	0.2954	0.0725	0.0419	T	0.614	0.000E+00	0.000E+00	0.000
373.629	100.5	420.9	0.5897	0.2962	0.0728	0.0413	T	0.614	0.000E+00	0.000E+00	0.000
375.629	100.3	420.1	0.5889	0.2973	0.0730	0.0408	T	0.615	0.000E+00	0.000E+00	0.000
377.629	100.2	419.4	0.5880	0.2984	0.0733	0.0403	T	0.616	0.000E+00	0.000E+00	0.000
379.629	100.0	418.7	0.5870	0.2996	0.0736	0.0398	T	0.617	0.000E+00	0.000E+00	0.000
381.629	99.9	418.1	0.5859	0.3008	0.0739	0.0394	T	0.618	0.000E+00	0.000E+00	0.000
383.629	99.8	417.5	0.5847	0.3021	0.0742	0.0390	T	0.618	0.000E+00	0.000E+00	0.000
385.629	99.6	417.0	0.5834	0.3035	0.0746	0.0386	T	0.619	0.000E+00	0.000E+00	0.000
387.629	99.5	416.6	0.5820	0.3049	0.0749	0.0382	T	0.620	0.000E+00	0.000E+00	0.000
389.629	99.4	416.2	0.5806	0.3063	0.0752	0.0378	T	0.620	0.000E+00	0.000E+00	0.000
391.629	99.4	415.6	0.5779	0.3088	0.0759	0.0374	T	0.622	0.000E+00	0.000E+00	0.000
393.629	99.4	415.2	0.5758	0.3108	0.0764	0.0370	T	0.624	0.000E+00	0.000E+00	0.000
395.629	99.3	414.9	0.5740	0.3125	0.0768	0.0367	T	0.625	0.000E+00	0.000E+00	0.000
397.629	99.3	414.6	0.5721	0.3143	0.0772	0.0364	T	0.626	0.000E+00	0.000E+00	0.000
399.629	99.3	414.4	0.5701	0.3162	0.0777	0.0361	T	0.627	0.000E+00	0.000E+00	0.000
401.629	99.2	414.2	0.5680	0.3181	0.0782	0.0358	T	0.628	0.000E+00	0.000E+00	0.000
403.629	99.2	414.0	0.5658	0.3201	0.0786	0.0354	T	0.629	0.000E+00	0.000E+00	0.000
405.629	99.2	413.8	0.5637	0.3221	0.0791	0.0351	T	0.630	0.000E+00	0.000E+00	0.000
407.629	99.2	413.7	0.5615	0.3240	0.0796	0.0349	T	0.631	0.000E+00	0.000E+00	0.000
409.629	99.2	413.6	0.5594	0.3259	0.0800	0.0346	T	0.632	0.000E+00	0.000E+00	0.000
411.629	99.3	413.5	0.5574	0.3278	0.0805	0.0343	T	0.633	0.000E+00	0.000E+00	0.000
413.629	99.3	413.5	0.5554	0.3296	0.0809	0.0340	T	0.634	0.000E+00	0.000E+00	0.000
415.629	99.3	413.1	0.5535	0.3314	0.0813	0.0338	T	0.635	0.000E+00	0.000E+00	0.000
417.629	99.3	412.7	0.5516	0.3331	0.0817	0.0335	T	0.637	0.000E+00	0.000E+00	0.000
419.629	99.3	412.5	0.5498	0.3349	0.0821	0.0333	T	0.638	0.000E+00	0.000E+00	0.000
421.629	99.3	412.2	0.5479	0.3366	0.0825	0.0330	T	0.639	0.000E+00	0.000E+00	0.000
423.629	99.3	412.0	0.5461	0.3383	0.0829	0.0327	T	0.640	0.000E+00	0.000E+00	0.000
425.629	99.3	411.9	0.5443	0.3399	0.0833	0.0325	T	0.641	0.000E+00	0.000E+00	0.000
427.629	99.3	411.8	0.5426	0.3415	0.0837	0.0323	T	0.642	0.000E+00	0.000E+00	0.000

429.629	99.3	411.8	0.5409	0.3431	0.0840	0.0320	T	0.643	0.000E+00	0.000E+00	0.000
431.629	99.3	411.8	0.5393	0.3446	0.0843	0.0318	T	0.644	0.000E+00	0.000E+00	0.000
433.629	99.3	411.8	0.5378	0.3460	0.0846	0.0316	T	0.644	0.000E+00	0.000E+00	0.000
435.629	99.3	411.8	0.5363	0.3474	0.0849	0.0314	T	0.645	0.000E+00	0.000E+00	0.000
437.629	99.4	411.9	0.5349	0.3487	0.0852	0.0311	T	0.646	0.000E+00	0.000E+00	0.000
439.629	99.4	412.1	0.5336	0.3500	0.0855	0.0309	T	0.646	0.000E+00	0.000E+00	0.000
441.629	99.4	412.2	0.5323	0.3512	0.0857	0.0307	T	0.646	0.000E+00	0.000E+00	0.000
443.629	99.4	412.4	0.5311	0.3524	0.0860	0.0305	T	0.647	0.000E+00	0.000E+00	0.000
445.629	99.4	412.7	0.5300	0.3535	0.0862	0.0303	T	0.647	0.000E+00	0.000E+00	0.000
447.629	99.5	412.9	0.5289	0.3545	0.0864	0.0301	T	0.647	0.000E+00	0.000E+00	0.000
449.629	99.5	413.2	0.5279	0.3555	0.0866	0.0300	T	0.647	0.000E+00	0.000E+00	0.000
451.629	99.5	413.5	0.5270	0.3565	0.0867	0.0298	T	0.647	0.000E+00	0.000E+00	0.000
453.629	99.5	413.9	0.5261	0.3574	0.0869	0.0296	T	0.647	0.000E+00	0.000E+00	0.000
455.629	99.6	414.3	0.5253	0.3582	0.0870	0.0294	T	0.647	0.000E+00	0.000E+00	0.000
457.629	99.6	414.7	0.5246	0.3590	0.0871	0.0292	T	0.647	0.000E+00	0.000E+00	0.000
459.629	99.6	415.2	0.5239	0.3598	0.0873	0.0291	T	0.647	0.000E+00	0.000E+00	0.000
461.629	99.7	415.7	0.5232	0.3606	0.0874	0.0289	T	0.647	0.000E+00	0.000E+00	0.000
463.629	99.7	416.3	0.5226	0.3613	0.0875	0.0287	T	0.647	0.000E+00	0.000E+00	0.000
465.629	99.8	416.8	0.5220	0.3620	0.0875	0.0285	T	0.646	0.000E+00	0.000E+00	0.000
467.629	99.8	417.5	0.5214	0.3626	0.0876	0.0283	T	0.646	0.000E+00	0.000E+00	0.000
469.629	99.9	418.2	0.5210	0.3632	0.0877	0.0282	T	0.646	0.000E+00	0.000E+00	0.000
471.629	99.9	418.9	0.5206	0.3638	0.0877	0.0280	T	0.645	0.000E+00	0.000E+00	0.000
473.629	100.0	419.7	0.5202	0.3643	0.0877	0.0278	T	0.644	0.000E+00	0.000E+00	0.000
475.629	100.1	420.6	0.5200	0.3647	0.0877	0.0276	T	0.644	0.000E+00	0.000E+00	0.000
477.629	100.1	421.5	0.5198	0.3651	0.0877	0.0274	T	0.643	0.000E+00	0.000E+00	0.000
479.629	100.2	422.4	0.5197	0.3654	0.0877	0.0272	T	0.642	0.000E+00	0.000E+00	0.000
481.629	100.3	423.5	0.5197	0.3657	0.0876	0.0270	T	0.641	0.000E+00	0.000E+00	0.000
483.629	100.4	424.6	0.5198	0.3659	0.0875	0.0268	T	0.640	0.000E+00	0.000E+00	0.000
485.629	100.5	425.9	0.5200	0.3660	0.0874	0.0265	T	0.639	0.000E+00	0.000E+00	0.000
487.629	100.5	427.2	0.5204	0.3661	0.0873	0.0263	T	0.638	0.000E+00	0.000E+00	0.000
489.629	100.6	428.7	0.5208	0.3660	0.0871	0.0261	T	0.636	0.000E+00	0.000E+00	0.000
491.629	100.7	430.3	0.5215	0.3658	0.0869	0.0258	T	0.634	0.000E+00	0.000E+00	0.000
493.629	100.9	432.1	0.5223	0.3655	0.0866	0.0255	T	0.632	0.000E+00	0.000E+00	0.000
495.629	101.0	434.0	0.5233	0.3651	0.0863	0.0253	T	0.630	0.000E+00	0.000E+00	0.000
497.629	101.1	436.2	0.5243	0.3648	0.0860	0.0249	T	0.627	0.000E+00	0.000E+00	0.000
499.629	101.2	438.5	0.5253	0.3644	0.0857	0.0246	T	0.625	0.000E+00	0.000E+00	0.000
501.629	101.3	441.0	0.5263	0.3642	0.0853	0.0242	T	0.622	0.000E+00	0.000E+00	0.000
503.629	101.4	443.8	0.5273	0.3639	0.0850	0.0238	T	0.619	0.000E+00	0.000E+00	0.000
505.629	101.6	447.0	0.5283	0.3637	0.0847	0.0233	T	0.615	0.000E+00	0.000E+00	0.000
507.629	101.7	450.7	0.5294	0.3636	0.0843	0.0227	T	0.611	0.000E+00	0.000E+00	0.000
509.629	102.0	455.2	0.5306	0.3635	0.0839	0.0220	T	0.606	0.000E+00	0.000E+00	0.000
511.555	102.3	460.4	0.5319	0.3635	0.0834	0.0213	T	0.601	0.000E+00	0.000E+00	0.000
512.861	102.5	465.6	0.5344	0.3623	0.0827	0.0206	T	0.595	0.000E+00	0.000E+00	0.000
514.335	102.9	472.3	0.5357	0.3624	0.0822	0.0196	T	0.590	0.000E+00	0.000E+00	0.000
515.513	103.3	479.5	0.5371	0.3626	0.0817	0.0186	T	0.584	0.000E+00	0.000E+00	0.000
516.459	103.9	487.9	0.5386	0.3628	0.0812	0.0175	T	0.577	0.000E+00	0.000E+00	0.000
518.353	103.6	485.6	0.5388	0.3626	0.0811	0.0175	F	0.578	0.000E+00	0.000E+00	0.000
519.982	102.9	476.3	0.5377	0.3624	0.0815	0.0184	F	0.585	0.000E+00	0.000E+00	0.000
521.768	102.3	467.7	0.5366	0.3622	0.0819	0.0193	F	0.592	0.000E+00	0.000E+00	0.000
523.080	101.9	462.2	0.5359	0.3622	0.0821	0.0198	F	0.597	0.000E+00	0.000E+00	0.000
524.522	101.4	456.8	0.5349	0.3624	0.0824	0.0203	F	0.601	0.000E+00	0.000E+00	0.000
526.136	101.0	451.3	0.5333	0.3630	0.0828	0.0208	F	0.606	0.000E+00	0.000E+00	0.000
527.047	100.9	448.4	0.5317	0.3640	0.0833	0.0211	F	0.609	0.000E+00	0.000E+00	0.000
528.260	100.6	444.7	0.5297	0.3652	0.0838	0.0214	F	0.613	0.000E+00	0.000E+00	0.000
529.455	100.4	441.4	0.5278	0.3664	0.0842	0.0216	F	0.617	0.000E+00	0.000E+00	0.000
530.689	100.2	438.2	0.5258	0.3676	0.0847	0.0219	F	0.621	0.000E+00	0.000E+00	0.000
532.002	100.0	435.1	0.5237	0.3690	0.0852	0.0221	F	0.624	0.000E+00	0.000E+00	0.000
533.400	99.8	432.0	0.5215	0.3705	0.0858	0.0223	F	0.628	0.000E+00	0.000E+00	0.000
534.894	99.6	428.9	0.5190	0.3721	0.0864	0.0225	F	0.632	0.000E+00	0.000E+00	0.000
536.495	99.4	425.9	0.5164	0.3739	0.0870	0.0226	F	0.636	0.000E+00	0.000E+00	0.000

538.221	99.3	422.5	0.5118	0.3774	0.0881	0.0227	F	0.642	0.000E+00	0.000E+00	0.000
540.221	99.1	419.1	0.5076	0.3805	0.0891	0.0228	F	0.647	0.000E+00	0.000E+00	0.000
542.221	99.0	416.0	0.5036	0.3835	0.0900	0.0229	F	0.652	0.000E+00	0.000E+00	0.000
544.221	98.9	413.1	0.4988	0.3872	0.0912	0.0228	F	0.658	0.000E+00	0.000E+00	0.000
546.221	98.9	410.3	0.4940	0.3909	0.0923	0.0228	F	0.664	0.000E+00	0.000E+00	0.000
548.221	98.8	407.8	0.4891	0.3948	0.0934	0.0227	F	0.669	0.000E+00	0.000E+00	0.000
550.221	98.8	405.4	0.4840	0.3988	0.0946	0.0226	F	0.675	0.000E+00	0.000E+00	0.000
552.221	98.8	403.0	0.4796	0.4022	0.0956	0.0225	F	0.680	0.000E+00	0.000E+00	0.000
554.221	98.8	400.7	0.4755	0.4054	0.0966	0.0225	F	0.685	0.000E+00	0.000E+00	0.000
556.221	98.8	398.5	0.4716	0.4083	0.0975	0.0225	F	0.690	0.000E+00	0.000E+00	0.000
558.221	98.8	396.5	0.4680	0.4111	0.0984	0.0225	F	0.695	0.000E+00	0.000E+00	0.000
560.221	98.8	394.5	0.4647	0.4136	0.0992	0.0226	F	0.700	0.000E+00	0.000E+00	0.000
562.221	98.8	392.7	0.4616	0.4159	0.0999	0.0226	F	0.704	0.000E+00	0.000E+00	0.000
564.221	98.8	391.0	0.4588	0.4180	0.1006	0.0227	F	0.708	0.000E+00	0.000E+00	0.000
566.221	98.8	389.6	0.4561	0.4200	0.1012	0.0227	F	0.712	0.000E+00	0.000E+00	0.000
568.221	98.9	388.4	0.4536	0.4218	0.1018	0.0228	F	0.715	0.000E+00	0.000E+00	0.000
570.221	98.9	387.2	0.4514	0.4234	0.1024	0.0228	F	0.718	0.000E+00	0.000E+00	0.000
572.221	98.9	386.1	0.4493	0.4250	0.1028	0.0229	F	0.721	0.000E+00	0.000E+00	0.000
574.221	98.9	385.0	0.4473	0.4264	0.1033	0.0230	F	0.724	0.000E+00	0.000E+00	0.000
576.221	99.0	384.0	0.4455	0.4277	0.1037	0.0230	F	0.726	0.000E+00	0.000E+00	0.000
578.221	99.0	383.1	0.4438	0.4290	0.1041	0.0231	F	0.729	0.000E+00	0.000E+00	0.000
580.221	99.0	382.2	0.4422	0.4301	0.1045	0.0232	F	0.731	0.000E+00	0.000E+00	0.000
582.221	99.0	381.3	0.4407	0.4313	0.1049	0.0232	F	0.733	0.000E+00	0.000E+00	0.000
584.221	99.0	380.5	0.4392	0.4323	0.1052	0.0233	F	0.736	0.000E+00	0.000E+00	0.000
586.221	99.0	379.7	0.4378	0.4333	0.1055	0.0233	F	0.738	0.000E+00	0.000E+00	0.000
588.221	99.1	379.0	0.4365	0.4343	0.1058	0.0234	F	0.740	0.000E+00	0.000E+00	0.000
590.221	99.1	378.2	0.4352	0.4353	0.1061	0.0234	F	0.742	0.000E+00	0.000E+00	0.000
592.221	99.1	377.5	0.4340	0.4362	0.1064	0.0235	F	0.743	0.000E+00	0.000E+00	0.000
594.221	99.2	379.0	0.4321	0.4376	0.1068	0.0235	F	0.742	0.000E+00	0.000E+00	0.000
596.221	99.2	378.3	0.4312	0.4382	0.1070	0.0236	F	0.744	0.000E+00	0.000E+00	0.000
598.221	99.2	377.5	0.4303	0.4389	0.1072	0.0236	F	0.745	0.000E+00	0.000E+00	0.000
600.221	99.2	376.8	0.4293	0.4396	0.1074	0.0237	F	0.747	0.000E+00	0.000E+00	0.000

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   b. Cold Leg Break MHA DC = 0.6 (straight) New Model (break flow and enthalpy)

   c. CONTEMPT 4 N Reactor Input Model

   d. Notes containing details of calculations of all volumes; concrete and steel areas; junction areas, elevations and loss coefficients; fog spray system locations, rates and drop sizes.

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